

EBASCO

REM III PROGRAM

**REMEDIAL PLANNING ACTIVITIES
AT SELECTED UNCONTROLLED
HAZARDOUS SUBSTANCE DISPOSAL SITES**



EPA CONTRACT 68-01-7250

EBASCO SERVICES INCORPORATED

SDMS Document



123647

VIN 001 0864

EPA WORK ASSIGNMENT NUMBER: 37-2LB8
EPA CONTRACT NUMBER: 68-01-7250
EBASCO SERVICES INCORPORATED

VINELAND CHEMICAL COMPANY SITE
FINAL DRAFT
REMEDIAL INVESTIGATION REPORT
PLANT SITE
VINELAND, NEW JERSEY

JUNE 1989

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JUNE 1989

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VIN 001 0868

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VIN 001 0869

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LIST OF ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AIC	Acceptable Chronic Intake
ARARs	Applicable or Relevant and Appropriate Requirements
ASC	Acceptable Soil Concentration
ASTM	American Society of Testing and Materials
AWQC	Ambient Water Quality Criteria
BEHP	bis(2-ethylhexyl)phthalate
BNA	Base-Neutral/Acid Extractables
°C	Degrees Centigrade
CDI	Chronic Daily Intake
CDL	Contract Detection Limit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CLP	Contract Laboratory Program
CRAVE	Carcinogen Risk Assessment Verification Endeavor
DMAA	Dimethyl Arsenic Acid
DQO	Data Quality Objectives
ECRA	New Jersey Environmental Cleanup Responsibility Act
EDTA	Ethylenediaminetetra-acetate
EM	Electro Magnetic Conductivity Survey
EP	Extraction Procedure
EPIC	Environmental Photographic Information Center
ER	Ebasco River Sampling Station
EW	Ebasco Well
FS	Feasibility Study
GPD	Gallons Per Day
GPM	Gallons Per Minute
HEA	Health Effects Assessment
HSL	Hazardous Substances List
IDL	Instrument Detection Limit
IRIS	Integrated Risk Information System
Kd	Partitioning Coefficient
LL	Lined Lagoon
MCLGs	Maximum Contaminant Level Goals
MCLs	Maximum Contaminant Levels
MEP	Multiple Extraction Procedure
MG/KG	Milligrams Per Kilogram
MG/L	Milligrams Per Liter
MMAA	Monomethyl Arsenic Acid
MSL	Mean Sea Level
MW	Monitoring Well
NCDC	National Climatic Data Center
NCP	National Contingency Plan
NJAC	New Jersey Administrative Code
NJDEP	New Jersey Department of Environmental Protection
NJPDES	New Jersey Pollution Discharge Elimination System
NOAA	National Oceanic and Atmospheric Administration
ODW	Office of Drinking Water
OHEA	Office of Health and Environmental Affairs
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyls
PMSA	Primary Metropolitan Statistical Area

LIST OF ACRONYMS (Cont'd)

PPB	Parts Per Billion
PPM	Parts Per Million
PSI	Pounds Per Square Inch
PVC	Polyvinyl Chloride
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RMCL	Recommended Maximum Contaminant Level
RfD	Reference Dose
SAS	Special Analytical Services
SNARL	Suggested-No-Adverse Response Level
SPDES	State Pollution Discharge Elimination System
SU	Standard Units
TCE	Trichloroethylene
TCL	Target Compound List
TOC	Top of Casing
TOC	Total Organic Carbon
UCS	Unconfined Compressive Strength
UG/L	Micrograms Per Liter
UL	Unlined Lagoon
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet
VES	Vertical Electrical Soundings
ViChem	Vineland Chemical Company

EXECUTIVE SUMMARY

The Vineland Chemical Company (ViChem) Plant Site Remedial Investigation (RI) is one of three RIs being performed for the ViChem work assignment. The RIs include:

- o The ViChem plant site proper;
- o The Blackwater Branch upstream of the plant to its confluence with the Maurice River; the Maurice River from the Blackwater Branch to Union Lake, approximately seven river miles downstream; and the Maurice River below Union Lake to the Delaware Bay, an approximate river distance of 25 miles; and
- o Union Lake, an 870-acre impoundment on the Maurice River.

The purpose of the ViChem Plant Site RI was to collect sufficient data to prepare a risk assessment and to perform a Feasibility Study (FS) to evaluate potential remedial alternatives for environmental media found to cause increased health risks. The risk assessment evaluated contamination within surficial soils, subsurface soils, residential soils, the groundwater beneath the site, and within some of the buildings and lagoons on site. The FS will concentrate on the soils, groundwater and some of the buildings and lagoons.

The ViChem site is ranked among the top 10 hazardous waste sites in New Jersey, and is ranked number 42 on the National Priorities List. ViChem has manufactured organic arsenical herbicides and fungicides at this plant since 1949.

Detailed information on past use, storage, and disposal of all process materials at the plant is not available. It is known that waste salts containing arsenic with a hazardous waste number K 031 were piled outdoors, and that precipitation contacting the piles flushed arsenic into the groundwater. Also, the plant previously discharged untreated process water into lagoons, and the water was allowed to percolate into the groundwater. The contaminated groundwater subsequently discharged into the Blackwater Branch and was distributed downstream in the Maurice River drainage system.

Previous investigations have shown elevated arsenic concentrations in surface waters and sediments extending approximately 26 river miles downstream of the plant to the Delaware Bay.

ViChem is located in the northwestern corner of the City of Vineland, New Jersey. The plant is located in a partly residential and partly industrial area.

The field work for this RI was conducted in two phases. Phase I took place in June and July of 1986. Surface water and sediment samples were obtained from the Blackwater Branch adjacent to the plant site. Phase II took place in 1987. In January, 1987, groundwater and air samples were collected to determine the type of well construction materials to use when installing monitoring wells and to determine the level of respiratory protection for field personnel. The remaining Phase II work took place from May through October, 1987. Activities included installing 36 monitoring wells and taking groundwater, soil, building dust, lagoon, surface water and sediment samples.

Five bench-scale treatability tests were performed. Chemical fixation and chemical extraction were performed on the soils, and adsorption, ion exchange and reverse osmosis were performed on the groundwater. The fixation test was performed to determine if arsenic in the soil could be chemically stabilized or physically bound to the soil such that leachable arsenic concentrations were less than 5 mg/l. The extraction test was performed to determine if arsenic could be removed from the soil to a concentration of 20 mg/kg, the background arsenic concentration in New Jersey soils and the New Jersey Department of Environmental Protection (NJDEP) guidance for arsenic cleanup in soils. The groundwater tests were conducted to determine if arsenic could be removed from pretreated groundwater to below 50 ug/l, the Federal Primary Drinking Water standard for arsenic.

The major findings of the ViChem Plant Site RI were as follows:

- o The groundwater in the upper aquifer beneath the site, called the upper sand in this RI report, is contaminated with substantial quantities of arsenic. The upper sand extends approximately 40 to 50 feet below the ground in the contaminated areas. The upper sand discharges an estimated 6 metric tons of arsenic per year to the Blackwater Branch, which can be distributed downstream in the Maurice River system. Contaminated groundwater apparently does not flow beneath the Blackwater Branch, nor is the groundwater below the upper sand significantly contaminated with arsenic.
- o The calculated present-day input of arsenic into the groundwater is 0.04 to 0.14 metric tons per year, far less than the calculated arsenic output. Therefore, the majority of the arsenic in the groundwater is believed to come from past contamination.

- o Soil samples collected above the water table showed localized spots of arsenic contamination. The contamination was generally found where expected, in areas of known or suspected past operating practices where arsenic was applied to the surface soil. This arsenic may leach into the groundwater. Soil samples below the water table showed less arsenic contamination. However, the arsenic is not tightly bound to the soils and may continue to desorb into the groundwater. Estimates prepared for the FS indicated that it may take many years for the arsenic concentration in groundwater to fall below 50 ug/l if all sources are removed.
- o Soil samples taken off site, and soil samples taken on site where past surface applications of arsenic were not suspected, generally had low arsenic concentrations. The data indicated that surface migration of soil contamination was not occurring to a significant degree.
- o The risk assessment considered a number of pathways whereby the public and the plant workers could be exposed to arsenic in the soils and groundwater. Exposure pathways were modeled on a worst case basis, using maximum contaminant concentrations, and on a most plausible basis, using mean contaminant concentrations. Worst case and most plausible risks to residents from exposure to soils were 1×10^{-4} and 6×10^{-7} , respectively. For workers, the worst case and most plausible risks from soil exposure were 4×10^{-3} and 2×10^{-7} , respectively. The health risks calculated for groundwater ingestion were very high. However, it is believed that no residents in the immediate vicinity of the site are using the arsenic contaminated groundwater at this time.
- o The treatability studies determined that chemical fixation and extraction were feasible methods to treat the contaminated soils, and adsorption of arsenic and ion exchange were feasible methods to treat the groundwater. The FS will evaluate these treatment methodologies.

The data collected in Phases I and II and the previous data were sufficient to meet the study objectives of performing a risk assessment and performing an FS to evaluate remedial alternatives for the contaminated soils and groundwater. Additional data needs were identified, including defining the total extent of the groundwater plume in peripheral areas; determining the nature of a very large arsenic maximum at one well; further defining on-site soil contamination if soil remediation were performed; and performing column leaching tests to better define arsenic desorption from the saturated and unsaturated soils.

VIN 001 0891

1.0 INTRODUCTION

The U.S. Environmental Protection Agency (USEPA) on May 9, 1986 authorized Ebasco Services Incorporated (Ebasco) to conduct a Remedial Investigation/Feasibility Study (RI/FS) on the Vineland Chemical Company (ViChem) site, Vineland, New Jersey. The RI/FS was performed in response to Work Assignment Number 37-2LB8 under Contract Number 68-01-7250. Preparation of this report was accomplished pursuant to the approved Work Plan for the ViChem site dated November 17, 1986 as amended in October 1987.

Three RI and three FS reports have been prepared for the ViChem site. The reports, the areas they cover, and the dates of submission to the USEPA are presented in Table 1-1.

The study area is approximately 38 miles long: 11 miles of riverine environment (including two miles upstream of the plant); 2 miles of lacustrine environment; and 25 miles of estuarine environment. This report addresses the ViChem plant site. The location of the study area is shown in Figures 1-1 and 1-2.

1.1 REMEDIAL INVESTIGATION OBJECTIVES

The objective of the ViChem Plant Site RI was to obtain the data required to conduct a risk assessment and to perform an FS to evaluate potential remedial alternatives. Specifically the ViChem Plant Site RI objectives were threefold:

- o Define the extent of contamination in the soil, groundwater and some of the buildings and lagoons in the ViChem plant site area;
- o Identify the contaminants and pathways that have actual or potential impacts on the public health or the environment; and
- o Conduct bench-scale studies to evaluate the feasibility of treating contaminated soil and groundwater, and evaluate the potential impacts of proposed remedial measures.

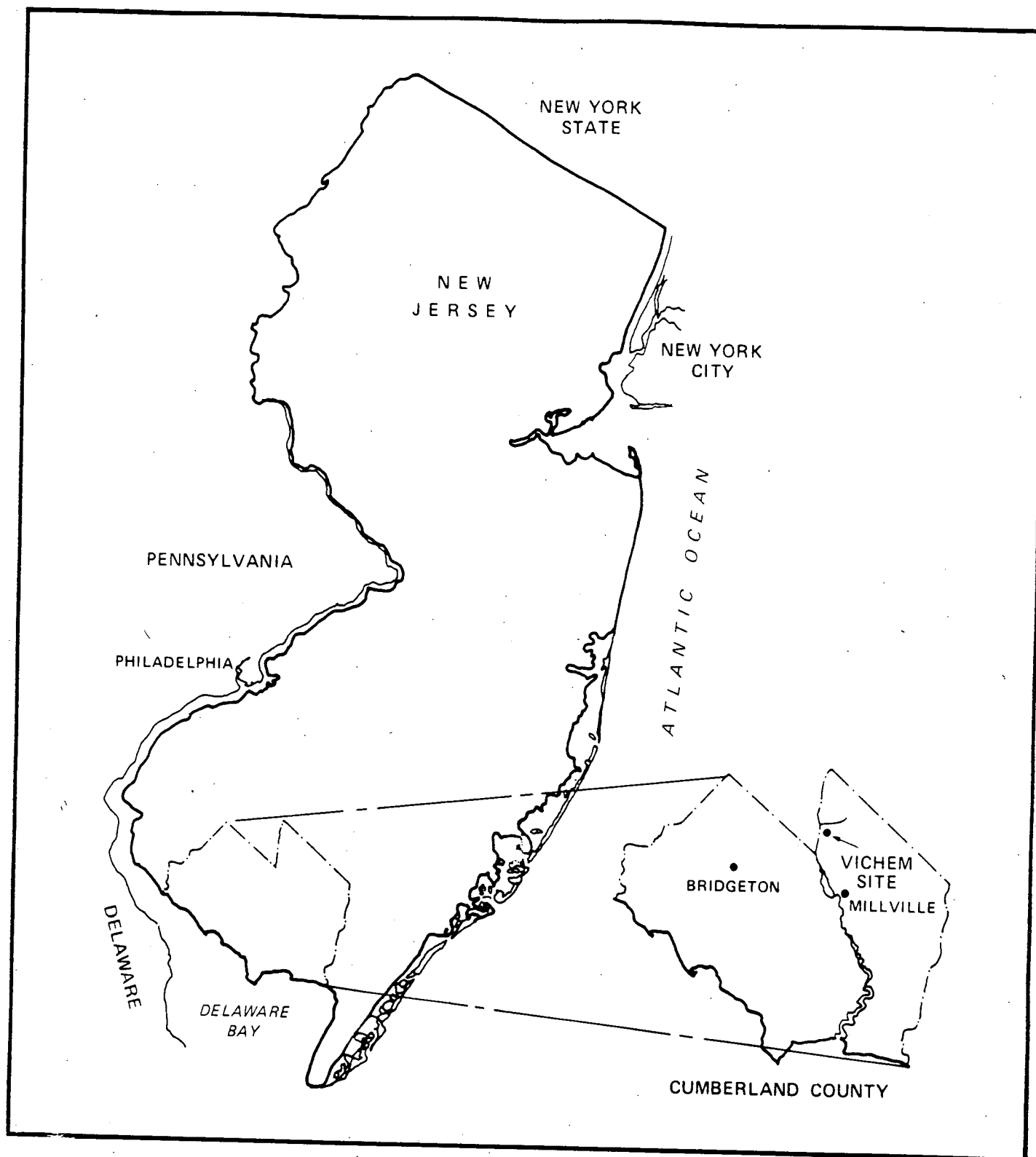
Ebasco performed field studies in 1986 and 1987 in order to generate data to carry out these objectives. Specific elements of the field program are described in Subsection 1.3.2 and in Section 2. In addition, treatability studies were performed to evaluate potential treatment technologies for contaminated soils and groundwater, as outlined in Section 7. This information was augmented with data from previous studies conducted for ViChem and the NJDEP. This overall data base provided the information to meet the RI/FS study objectives. Additional data will be necessary to fully determine the extent of soil and groundwater contamination during remedial design activities.

TABLE 1-1

RI AND FS REPORTS PREPARED FOR THE VINELAND CHEMICAL COMPANY SITE

<u>TITLE</u>	<u>AREAS</u>	<u>MEDIA INVESTIGATED</u>	<u>DRAFT</u>	<u>REVISED DRAFT</u>	<u>FINAL DRAFT</u>
Plant Site RI	ViChem Plant Site	Soil, Groundwater	7/19/88	3/10/89	6/23/89
River Areas RI	Blackwater Branch, Maurice River between Blackwater Branch and Union Lake, Maurice River below Union Lake to Delaware Bay	Sediment, Surface Water, Biota	9/8/88	2/17/89	6/23/89
Union Lake RI ⁽¹⁾	Union Lake	Sediment, Surface Water, Biota	6/21/88	4/28/89	6/23/89
Plant Site FS	ViChem Plant Site	Soil, Groundwater	9/20/88	3/10/89	6/23/89
River Areas FS ⁽²⁾	Blackwater Branch, Maurice River between Blackwater Branch and Union Lake	Sediment	10/5/88	2/17/89 ⁽³⁾	6/23/89
Union Lake FS	Union Lake	Sediment	1/18/89	4/14/89	6/23/89

- 1 Risk assessment submitted on April 20, 1987. First Draft RI submitted on March 13, 1988. The June 21, 1988 RI incorporated the first revised risk assessment.
- 2 No FS Report is being prepared for the Maurice River below Union Lake.
- 3 This report was reissued on April 27, 1989 containing a revised action level for the sediments.



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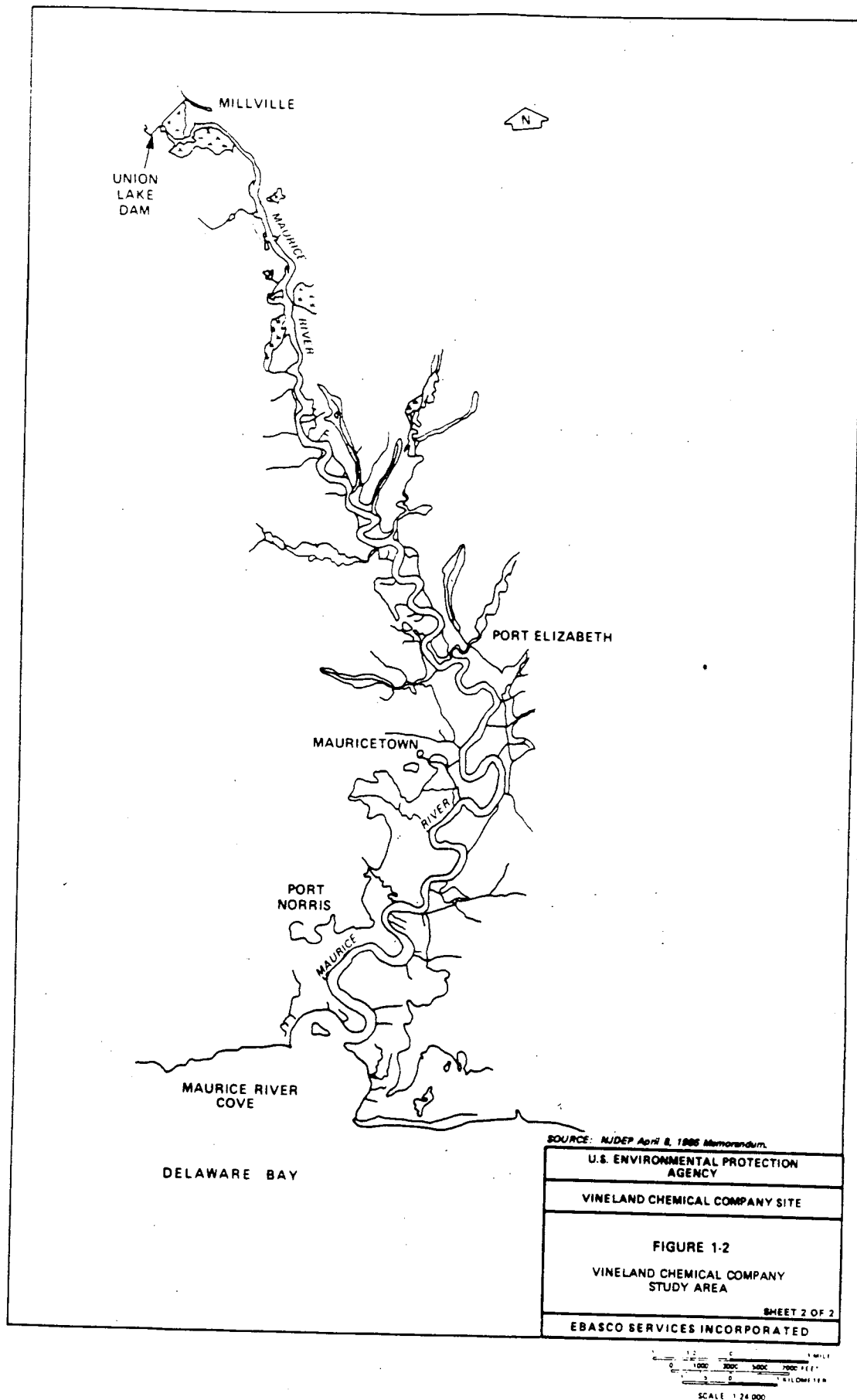
VINELAND CHEMICAL COMPANY SITE

FIGURE 1-1

VINELAND CHEMICAL COMPANY
REGIONAL LOCATION MAP

EBASCO SERVICES INCORPORATED

VIN 001 0894



1.2 BACKGROUND INFORMATION

1.2.1 Site Description

The ViChem plant is located in a residential/industrial area in the northwest corner of the City of Vineland in Cumberland County, New Jersey. The plant location is shown in Figure 1-3.

The plant is bordered on the north by Wheat Road and the Blackwater Branch, a tributary of the Maurice River. Residential areas border the plant to the east, west and south along Orchard, Oak and Mill Roads, as shown in Figure 1-4.

ViChem has produced organic herbicides and fungicides at this location since 1949. ViChem currently produces two major herbicidal chemicals, disodium methanearsonate and monosodium methanearsonate. Table 1-2 lists chemicals used, manufactured, or known to be stored at the ViChem plant.

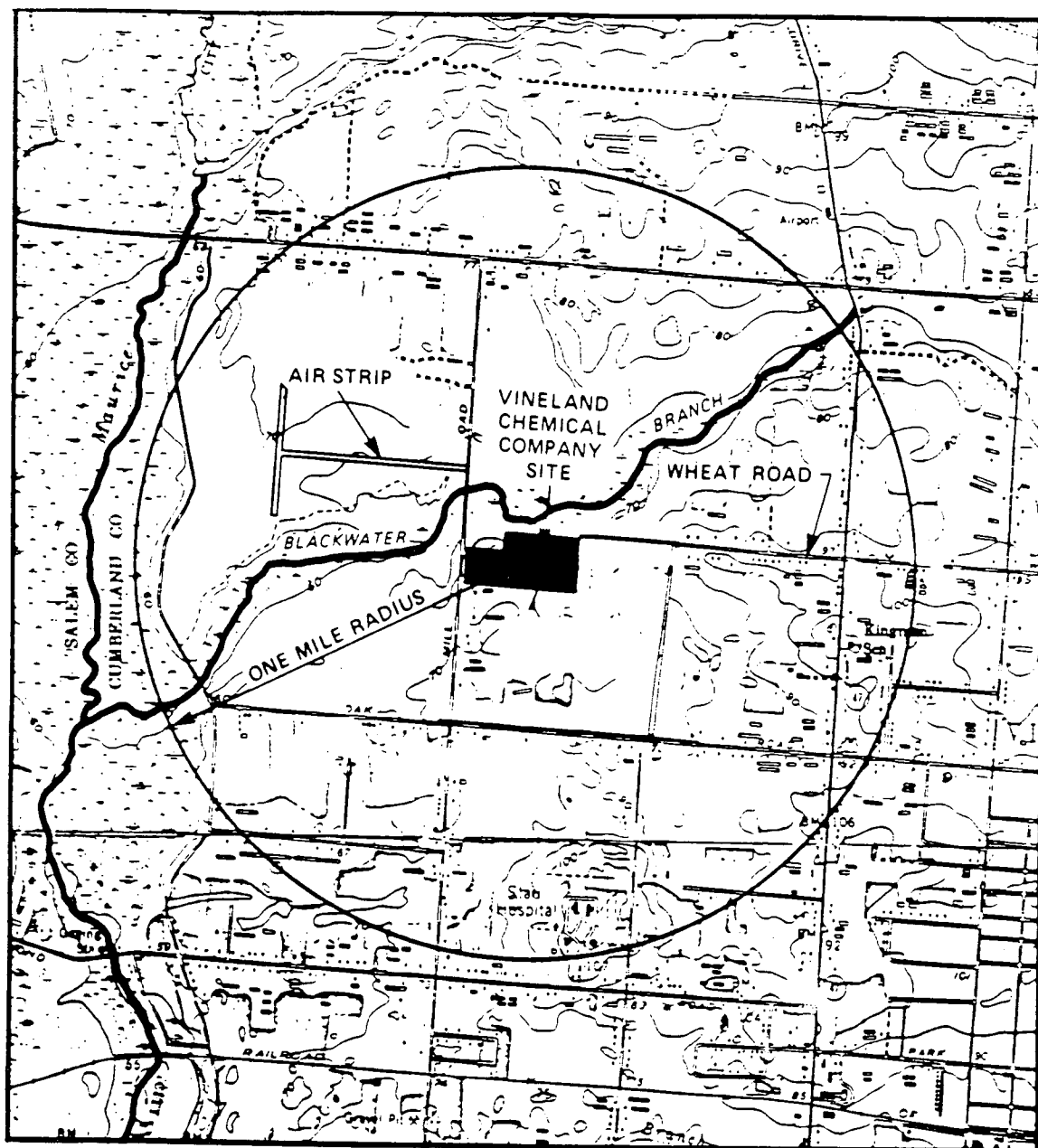
The ViChem plant site is shown in Figure 1-5. The plant consists of several manufacturing and storage buildings, a laboratory, a worker change facility, a wastewater treatment plant and several lagoons. The manufacturing and parking areas shown in Figure 1-5 are paved. The lagoon area is unpaved and devoid of vegetation. This area is dominated by loose sandy soils. The remainder of the site is covered by trees, grass, or shrubs.

The site is situated in a residential/industrial area. Twelve residences are shown in Figure 1-5 in the immediate vicinity of the plant. A number of other residences are located close to the plant along Wheat, Orchard, Oak, and Mill Road as shown in Figure 1-4.

The Martex Manufacturing facility is located immediately north and west of the ViChem lagoon area. Martex reportedly produces packaging materials, although little information is available on the materials used or manufactured at this site.

The Blackwater Branch is immediately north of the ViChem plant. This stream flows east to west and discharges into the Maurice River approximately 1.5 miles downstream from the plant. The upper Maurice River, shown in Figure 1-2, then flows approximately seven river miles downstream into Union Lake, which is approximately two miles long. The Maurice River then flows approximately 25 river miles downstream from Union Lake to the Delaware Bay as shown in Figure 1-2.

Some time between April 1985 and June 1986, beavers constructed a dam on the Blackwater Branch just downstream from the Mill Road bridge. The dam flooded the Blackwater Branch to the approximate extent shown in Figure 1-5. The dam was removed in October 1987 to allow for construction of a new bridge. The Blackwater Branch is now flowing in its normal channel and the flooded areas have been drained.



SCALE 1:24,000

0 1 MILE

BASE MAP PREPARED BY U.S.G.S. 1977

U.S. ENVIRONMENTAL PROTECTION
AGENCY

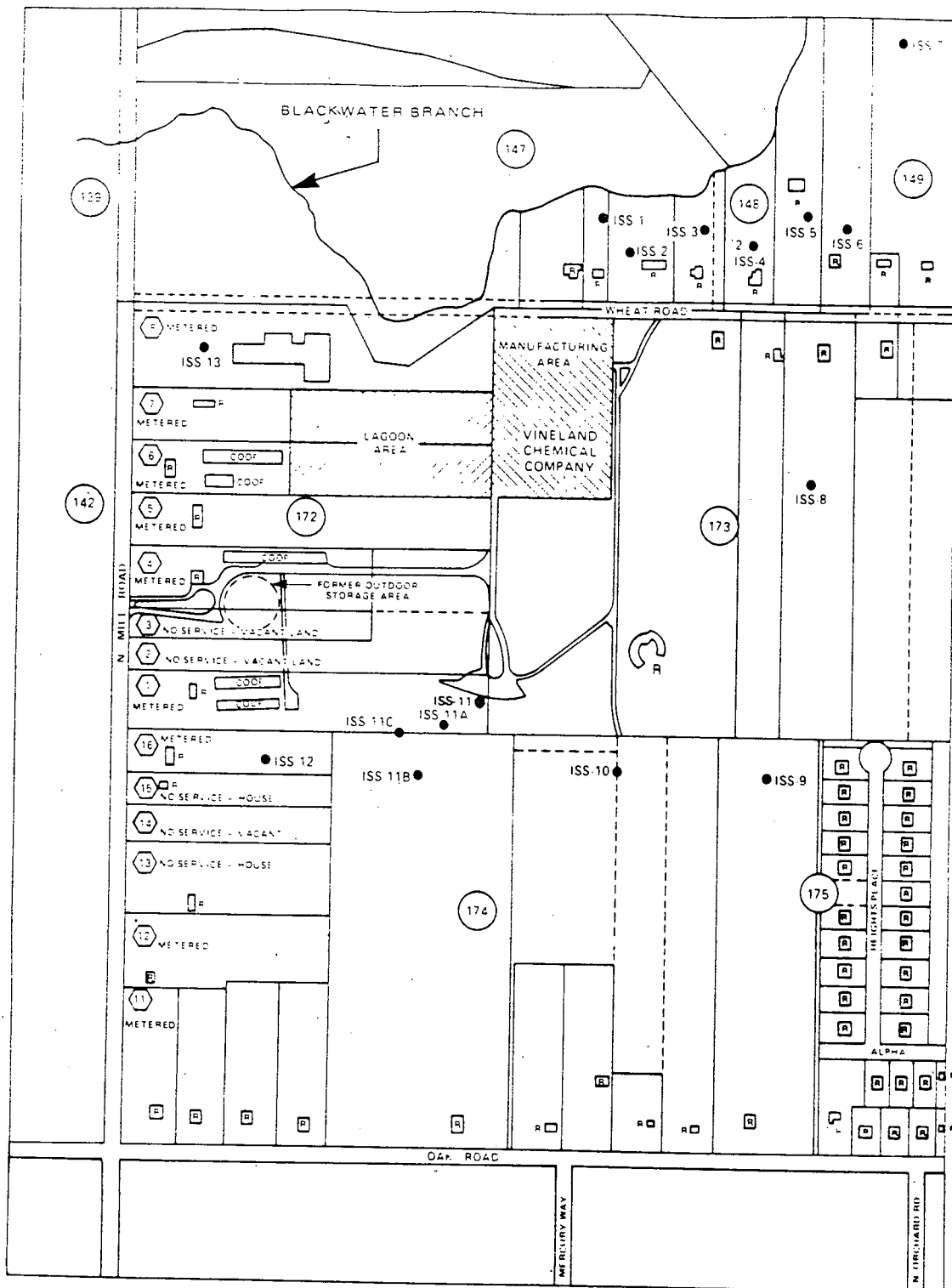
VINELAND CHEMICAL COMPANY SITE

FIGURE 1-3

VINELAND CHEMICAL COMPANY
ONE MILE RADIUS

EBASCO SERVICES INCORPORATED

VIN 001 0898



LEGEND:

- 172 BLOCK NUMBER
- SOIL SAMPLING LOCATIONS
- R RESIDENCES
- ⬡ LOT NUMBER



0 200 400 600 800
SCALE IN FEET

BASE MAP PREPARED BY CITY ENGINEER, WILLIAM G. AUSTIN, CITY OF VINELAND, OCTOBER 1971.

U.S. ENVIRONMENTAL PROTECTION AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 1-4

RESIDENTIAL SOIL SAMPLING LOCATIONS AND WATER SUPPLY ALONG N. MILL ROAD

EBASCO SERVICES INCORPORATED

TABLE 1-2

CHEMICALS USED, MANUFACTURED OR STORED AT VINELAND CHEMICAL PLANTINORGANIC METALS AND SALTSFLOCCULANTS

Arsenic
 Mercury
 Mercury (II) chloride
 Mercury (I) chloride
 Cadmium
 Cadmium chloride

Aluminum
 Iron

METAL ORGANIC ARSENIC COMPOUNDS

Disodium methane arsonate
 Dodecyl and octylammonium methane-arsonate
 Monosodium acid methane arsonate
 Calcium acid methane-arsonate
 Dimethylarsonic acid (Cacodylic acid)

ORGANIC MERCURY COMPOUNDS

Phenyl mercury dimethyldithiocarbamate
 Phenyl mercuric acetate

HERBICIDES

Sodium 2,4-dichlorophenoxy acetate
 2-4-dichlorophenoxy acetic acid (2,4D)
 2(4-chloro-2-methyl phenoxy) propanoic acid (MCP)
 bis(dimethylthio-carbonyl)disulfide (thiram)
 1,4-bis (bromoacetoxy)-2-butene
 2,3-dibromopropionaldehyde
 Alkylaryl polyether alcohol

SOLVENTS AND GENERAL ORGANIC CHEMICALS

Benzyl alcohol
 Xylene
 2,3 Benzofuran

Methyl chloride
 Methylene chloride
 Trichloroethane
 Trichloroethylene

Methylene-bis-thiocymate
 Hydrobromic acid

Methanol
 Epichlorohydrin
 Acrolein
 Isopropyl alcohol

Tetrachloroethylene
 Bromochloromethane

Tetrabutyl ammonium bromide
 Bromo acetic acid

TABLE 1-2 (Cont'd)

CHEMICALS USED, MANUFACTURED OR STORED AT VINELAND CHEMICAL PLANT

SOLVENTS AND GENERAL ORGANIC CHEMICALS (Cont'd)

Glycerine
Triton X-100
Formaldehyde
Butanediol

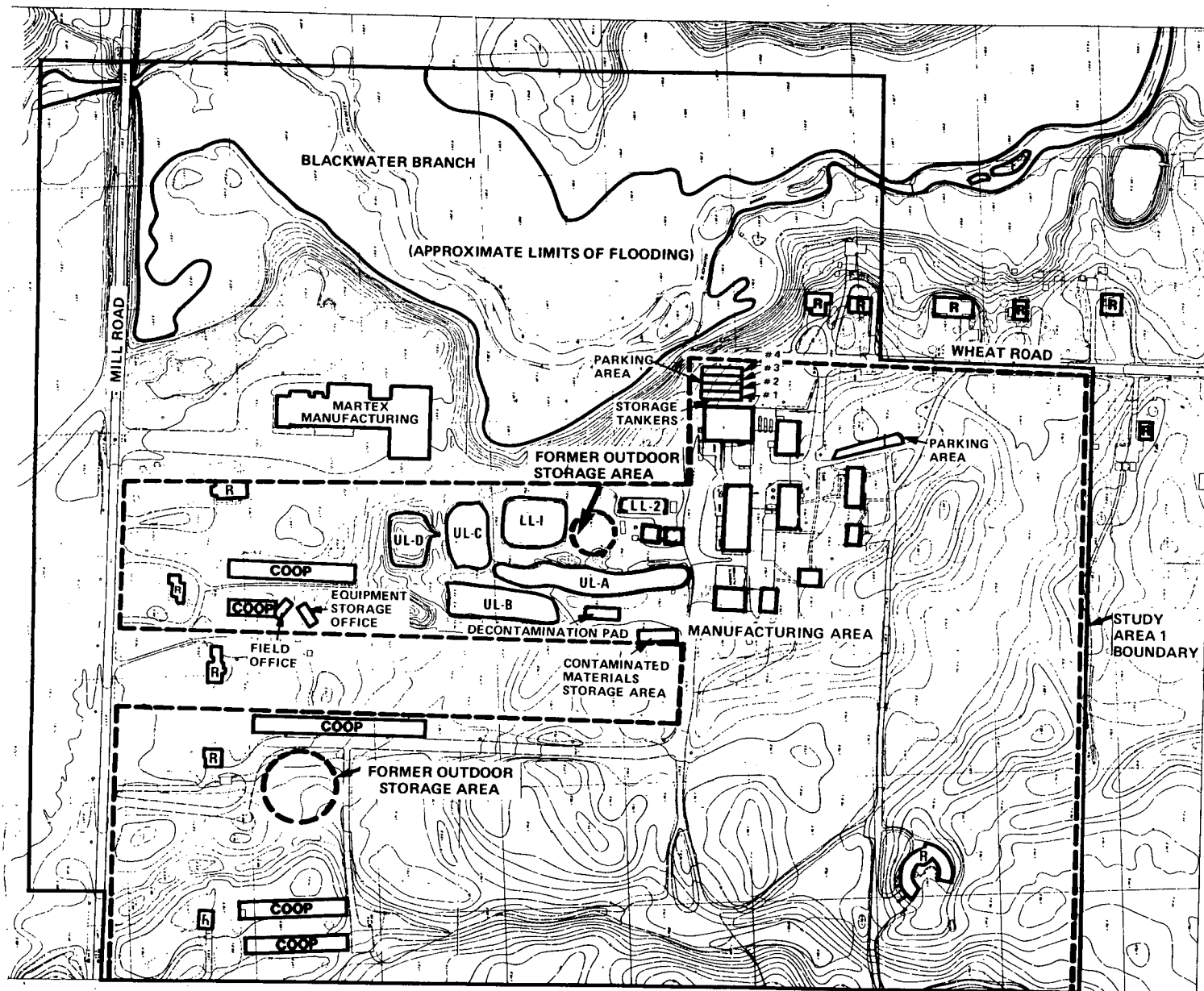
Gasoline
Kerosene

POSSIBLE CHEMICALS FROM MANUFACTURING

Phenol
Chlorophenols
Chloroacetic acid
Chlorides
Arsenic trioxide
Arsenic pentoxide
Methyl chloride
Methanol
Sodium hydroxide
Calcium oxides, chlorides, sulfates
Mercury oxides
Cadmium salts

- Compiled from
- 1) Miller, F., NJDEP Memo, Vineland Chemical Ground Water Pollution Problem, 24 May 1985
 - 2) Sittig, M., Pesticide Manufacturing and Toxic Materials Control Encyclopedia, Noyes Data Corp., Park Ridge NJ (1980)

VIN 001 0902



- R RESIDENCES
 --- VICHEM PROPERTY BOUNDARY
 LL LINED LAGOON
 UL UNLINED LAGOON

0 100 200 300
 SCALE IN FEET

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF
 ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1988

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 AGENCY

VINLAND CHEMICAL COMPANY SITE

FIGURE 1-5

VINLAND CHEMICAL COMPANY
 SITE PLAN

EBASCO SERVICES INCORPORATED

VIN 001 0902

A wastewater treatment system is in operation at the ViChem plant. The system has a design capacity of approximately 25 gallons per minute (gpm), or 36,000 gallons per day (gpd) assuming 24 hours of operation. The system was designed to treat between 2,000 and 5,000 gpd of process water, 20,000 gpd of groundwater that was to be pumped from the shallow water table, and storm runoff water as necessary. In addition, provisions were made to collect up to 60,000 gpd of non-contact cooling water in the event that a mechanical breakdown occurred and mixed the non-contact cooling water with the contaminated process water.

The wastewater treatment system consists of mix tanks, a reactor, filters and ancillary equipment. Ferric chloride is added to the first mix tank and caustic soda is added to the second mix tank to promote flocculation. The wastewater then enters the reactor where it is mixed with a polymer. This mixture then passes through a flocculation compartment where the large particles settle to the bottom and are removed to a rubber-lined tank. The reactor effluent is polished by a tertiary filter before discharge. The slurry in the rubber-lined tank is pumped into a vacuum filter and the dry solids are deposited in a dumpster for off-site disposal. Any liquid not meeting discharge requirements is reportedly recirculated for treatment.

Some of the lagoons shown in Figure 1-5 are used in the wastewater treatment system. Lagoon LL-1 is a lined lagoon with a 490,000 gallon capacity. This lagoon was designed to hold process water, groundwater, and storm water as necessary prior to treatment. Water can be pumped from this lagoon to the wastewater treatment plant at 25 gpm. Lagoon LL-2 is also a lined lagoon but it has a concrete base. It was previously used to store the arsenic-contaminated waste salt K 031 produced as a by-product of the herbicide manufacturing process, and later was used to hold the treatment plant sludge prior to disposal. It now holds water to be recirculated for retreatment. Lagoon UL-A is an unlined lagoon. This lagoon receives the non-contact cooling water and the treated discharge from the treatment plant. Because the site soils are sandy and this lagoon is unlined, water in the lagoon rapidly infiltrates into the groundwater.

The remaining lagoons shown in Figure 1-5, UL-B, UL-C, and UL-D, are all unlined and are not currently used in the water treatment system. However, aerial photographs provided by the USEPA's Environmental Photographic Information Center (EPIC) used in the USEPA's Site Analysis, Vineland Chemical Company (Simpson, 1988) show that UL-A, UL-B, UL-C, UL-D and LL-1 (which was previously unlined) were connected to one another in the past. The photographs show that all of the lagoons were filled with liquid.

VIN
001
0903

The two lined lagoons, LL-1 and LL-2, are regulated by RCRA. The wastewater treatment plant and the unlined lagoon, UL-A are regulated under the NJPDES program. Other active solid waste management units at the plant site include: trailers/tote bins used to store the K 031 waste salts and the treatment plant sludge; a septic system and leach field; and the soil beneath the floors of the production buildings, where past operating procedures reportedly produced spillage. Inactive/abandoned solid waste management units are basically areas where waste salts were improperly stored in the past, including the waste salt piles, sludge piles, chicken coops, and outdoor drum storage areas.

The treatment plant was designed to produce an effluent with an arsenic concentration of 0.05 milligrams per liter (mg/l). ViChem initially had difficulties achieving this level. An interim standard of 0.7 mg/l was therefore agreed to and ordered by NJDEP on December 22, 1981, with the understanding that the 0.05 mg/l level would eventually be met. In-house analytical results performed on a daily basis by ViChem indicate that the effluent has been reduced below the interim standard. The levels are still greater than 0.05 mg/l when the influent concentrations are high, but are less than 0.05 mg/l when the influent concentrations are low.

ViChem reports that it no longer treats either groundwater or process water. Reportedly all of the water used in manufacturing the herbicides is consumed by the process and is included as inherent moisture in the product. ViChem ceased pumping and treating groundwater in July 1987 with the consent of the NJDEP. One of the reasons the NJDEP allowed ViChem to stop pumping and treating groundwater was the NJDEP's concern that the treatment plant effluent, whatever its arsenic concentration, would cause a groundwater mound, driving existing contamination deeper into the groundwater and promoting off-site migration. The wastewater treatment plant now reportedly treats only storm water runoff on an intermittent basis.

The herbicide manufacturing process produces approximately 1,107 tons of waste by-product salts each year. These salts have an EPA hazardous waste number of K 031 and are neither treated nor disposed of at the site, nor stored on-site for more than 90 days. The salts are transported by licensed shippers to licensed facilities in Ohio and Michigan for disposal.

1.2.2 Site History

ViChem began manufacturing organic arsenical herbicides and fungicides at this plant in approximately 1949. In addition to arsenical herbicides, the company also produced cadmium based herbicides and used other inorganics such as lead and mercury. Table 1-2 presented a list of chemicals used, manufactured, or stored at the ViChem plant.

As early as 1966, the NJDEP observed ViChem discharging untreated wastewaters with unacceptable arsenic concentrations (67 mg/l) into the unlined lagoons. An unknown quantity of arsenic rapidly infiltrated into the groundwater from the lagoons. On February 8, 1971, ViChem was ordered to install and provide industrial wastewater treatment and/or disposal facilities. The wastewater treatment works did not become operational until March 1980.

Waste salts from the herbicide production process were stored on-site in uncontrolled piles on the soil, in the concrete lagoon LL-2 (which at the time was unlined), and in abandoned chicken coops on the plant property. The storage of salts in piles was observed in April 1970 and in the coops in April 1973. It was not until 1978 and many court orders that the salts were containerized and removed. These salts reportedly contained one to two percent arsenic (Woodward-Clyde, 1985). As these salts have a high solubility, precipitation contacting these piles rapidly dissolved the salts, carrying an unknown quantity of arsenic into the groundwater.

Between 1975 and 1976, ViChem was "fixating" the waste salts for disposal at the Kin-Buc Landfill. The process involved mixing the dried salts with ferric chloride and soda ash, reportedly reducing the solubility. The process was stopped in 1976 when the Kin-Buc Landfill voluntarily stopped accepting all chemical wastes, including the fixated salts. ViChem then resumed piling the untreated waste salts on the soil surface at the plant site.

A court order issued on January 26, 1977 required ViChem to containerize the waste salts from the chicken coops and piles, then store the drums in a warehouse off-site. In June 1979, another order was issued for the disposal of the stored drums in an approved landfill. Removal and disposal of these drums was not completed until June 30, 1982.

Currently, the waste salts, and the sludge from the wastewater treatment system, are stored in large capacity trailers and tote bins. The tote bins are filled at the point of generation in the manufacturing buildings, and then emptied into the trailers. The NJDEP believes that releases from this system are unlikely. The salts and sludge are transported to the licensed facilities mentioned above. During peak production, as many as four or five trailers are filled and removed per week.

Aerial photographs provided by the EPA's Environmental Photographic Information Center (EPIC) and conversations with ViChem employees indicated several possible locations of past contamination. The cleared area in the southwest corner of the site shown as a "former outdoor storage area" in Figure 1-5 used to be occupied by two chicken coops. Sometime between November 1975 and March 1979, both coops were destroyed. These coops were reportedly used to store process chemicals and/or waste in the 1970s. The materials stored in the coops may have perco-

lated into the groundwater. This area is now devoid of vegetation. Photographs show many locations containing mounded material and/or drums. These were observed in the lagoon area and along the plant road. The waste salts were reportedly mounded so high at times in lagoon LL-2 that the salts spilled over onto the soil in the lagoon area.

It is alleged that the floors of the manufacturing have been leaking arsenic compounds into the underlying sands for years. The original floors of the buildings were brick and were allegedly in need of repairs several years ago. Allegedly, when the old bricks were removed, the soil contained crystalline waste from previous spills. It is not known whether the soils were removed when the floors were replaced, although in Ebasco's Phase II investigation the soils below building number 9 were sampled and had high arsenic concentrations (Section 4). The floor of this building was solid and in good repair during Ebasco's 1987 investigation.

In response to a series of Administrative Consent Orders issued by the NJDEP, ViChem instituted some cleanup actions and modified the production process. The cleanup actions included stripping the surface soils in the manufacturing area, piling these soils in the clearing by well cluster EW-15, and paving the manufacturing area; installing a storm water runoff collection system; removing the piles of waste salts; and installing a groundwater pump and treat system including the wastewater treatment plant. Modifications to the production process included modifying the water system so that mixing of process water and non-contact cooling water was unlikely, lining two of the lagoons used in the wastewater treatment system, (LL-1 and LL-2) and properly disposing of the waste salts off-site.

Evidence suggested that a serious groundwater contamination problem existed at the ViChem site and that the groundwater was discharging into the streams and degrading the downstream water quality. Therefore, this RI/FS was undertaken to investigate the extent of the soil and groundwater contamination and to evaluate remedial alternatives for rehabilitating the soil, groundwater, downstream sediments and surface waters.

1.2.3 Permit Actions

On December 2, 1985, the USEPA informed ViChem that its interim status for the lined RCRA impoundments was terminated as a matter of law on November 8, 1985 because of failure to comply with Section 3005(e)2 of RCRA. The USEPA determined that the company (a) failed to certify compliance with the applicable financial assurance requirements for closure and post-closure care, (b) failed to certify that required liability insurance was ever actually obtained, and (c) failed to certify the preparation of a groundwater monitoring program meeting the requirements applicable to interim facilities. The company was to cease placing hazardous waste into the two lined lagoons.

ViChem submitted applications for RCRA and NJPDES permits. The RCRA permit application was for storage of hazardous wastewaters in the two lined lagoons. The NJPDES discharge to groundwater permit application was for discharge to the unlined lagoon UL-A.

In April, 1986, the NJDEP advised ViChem of its intent to deny both the RCRA and NJPDES permits. The technical and administrative bases for the tentative decision to deny the NJPDES permit are: (a) the discharge of 200,000 gallons per day (gpd) of non-contact cooling water into the unlined lagoons increased hydraulic gradients, thereby forcing contaminated groundwater deeper into the aquifer and further off-site; and (b) the treatment works were unable to meet the discharge criterion of 0.05 mg/l for arsenic. The technical bases for denying the RCRA permit application were inadequate closure, post-closure, and liability assurance requirements, and an inadequate groundwater monitoring program. The administrative basis for denial was the failure to submit a complete hazardous waste facility permit application given adequate time to do so. The NJPDES permit has been denied, but is being appealed by ViChem.

1.2.4 Previous Investigations

Since 1978, a number of studies have been performed by or for the NJDEP Office of Science and Research in the Maurice River watershed and at the ViChem plant site. ViChem itself has also conducted some investigations into the groundwater plume at the plant.

In 1979 and 1980, the NJDEP initiated a sampling program in the Blackwater Branch and the Maurice River downstream from the site. The results showed that the sediment arsenic concentrations in the Maurice River were the highest observed anywhere within the State of New Jersey. The study showed that the Almond Road weir, the submerged dam in Union Lake, the lower main dam in Union Lake, and the tidal creeks of the Maurice River estuary below Union Lake stored arsenic contaminated sediments. Elevated arsenic concentrations were found in sediments as far from the site as the Delaware Bay, approximately 36 river miles downstream. Also, the arsenic concentration in the surface water decreased downstream from the site but did not reach the Federal Primary Drinking Water Standard for arsenic, 0.05 mg/l or 50 ug/l, until 26.5 river miles downstream from the ViChem site.

In 1978, ViChem commissioned a surface geophysical survey of the site at the direction of the NJDEP. The survey noted areas of probable contamination were the lagoon area, the area north of the lagoons to the Blackwater Branch, the former outdoor storage area shown in Figure 1-5, and along the plant road between the former outdoor storage area and the lagoons. The report also contended that the probable groundwater contamination was shallow and recommended locations for installing extraction wells.

In 1979, NJDEP sampled soils in the ViChem plant area. Samples were taken at the surface and at depth. The study showed arsenic concentrations ranging from undetected to 864 mg/kg at various locations in the plant area.

In 1981, the NJDEP performed a surface geophysical survey of the plant area. The study identified two areas of probable groundwater contamination, one northwest of the lagoons toward the Blackwater Branch and the other near the former outdoor storage area. The study estimated that the probable maximum depth of the contaminant plume was approximately 40 feet.

In 1982, ViChem commissioned a groundwater investigation of the site. In this study, previous investigations were reviewed and a scheme to remove arsenic from the contaminated aquifer was proposed. This study included several sets of water quality data. Approximately 4 1/2 years of monthly arsenic concentrations at ViChem well MW-1 were presented along with data from ViChem wells MW-6 and MW-10. These data showed a marked drop in the arsenic concentration in the groundwater between 1978 and 1981. The study also presented monthly levels of arsenic in the Blackwater Branch at Mill Road, and in the Maurice River at the Almond Road weir. The study postulated that the arsenic load at Mill Road was very similar to the arsenic load at Almond Road, implying that the river system was essentially a conduit for arsenic transport into Union Lake. The study reviewed processes for arsenic cleanup at the site and recommended a groundwater pump and treat program along with controlled soil leaching.

In 1982, an employee of ViChem was diagnosed as having subacute arsenic poisoning. The New Jersey Department of Health then conducted a "Cross-Sectional Evaluation of Arsenic Exposure and Toxicity at the Vineland Chemical Company." The study revealed that employees had elevated arsenic concentrations in their hair and urine, but only exhibited minor symptoms associated with arsenic trioxide dust on the skin and mucous membranes. As a result of this survey, the arsenic handling practices in the production facility improved.

Two studies were conducted by the NJDEP and Rutgers University from 1980 to 1982 in Union Lake. The studies showed that Union Lake is chemically stratified during the summer. This stratification creates seasonal anaerobic conditions in the bottom sediments, which are conducive to the formation of toxic arsenical compounds from the contaminated sediments (NJDEP, 1986). The Rutgers University work included sampling and analysis of water and sediments, as well as speciation of arsenic [trivalent (As III), pentavalent (As V), monomethyl arsenic acid (MMAA) and dimethyl arsenic acid (DMAA) (Faust, 1983)]. This study concluded that the waters and bottom sediments were highly contaminated

with substantial quantities of arsenic, and that total arsenic concentrations in all lake water samples exceeded the NJDEP and EPA drinking water standard of 50 ug/l. In sediments, the order of predominance of the four arsenic species (in descending order) was: As (V), As (III), MMAA, DMAA. In four of the sediment samples, the inorganic arsenate was between 73% and 88% of the total arsenical species. In water, the order of predominance was MMAA, As (III), As (V), DMAA. The results of the sampling efforts revealed a seasonal pattern of arsenic concentrations within the lake water with the greatest concentrations occurring during the summer. Additional NJDEP sediment sampling near the spillway area of Union Lake in April, 1986 again showed arsenic contamination within the sediments and showed that contamination within the sediments was a surficial phenomenon.

In a 1983 to 1985 study by Rutgers University (Winka, 1985), it was shown that arsenic may exist in many species in the watershed and that these species may be transformed by changes in physical condition and season. Results indicated that within the water column the inorganic arsenic species may be one half of the total arsenic. Arsenic was not easily solubilized under aerobic conditions. The concern raised by these findings was that when an anaerobic condition developed on the bottom of Union Lake, the arsenic would be readily converted into the more toxic As (III) and As(V) forms. The more toxic forms could then be released to the water column upon seasonal turnover of the stratified layers. However, as these compounds are relatively insoluble, they were expected to precipitate back to the lake bottom within a relatively short period of time.

In 1982, ViChem commissioned a pumping test to be performed on the shallow aquifer underlying the lagoon area. The pumping test estimated a transmissivity in the shallow aquifer of approximately 50,000 gpd/ft, and a storage coefficient of between 0.1 and 0.04.

In 1985, ViChem's RCRA Part B permit application was submitted to the NJDEP. The application included a description of the wastewater and groundwater handling and a description of the wastewater treatment process and facility design. The application also included data on the production rate at the plant and the toxicity of the wastes generated. Arsenic concentrations in the Blackwater Branch through time were also presented.

In 1986, ViChem commissioned a pumping test to be performed in the deeper groundwater below the site. The plant's production well, screened from 130 to 165 feet below the ground, was used as the pumping well and a deep monitoring well was installed in the lagoon area. The pumping test was conducted for 24 hours, with water levels measured in the deep monitoring well and several shallow monitoring wells near the discharge in the lagoon area. The report concluded that the "clay layer"

reportedly encountered from 120 to 135 feet below the ground and which the production well is screened below acts as a confining layer and prevents downward migration from the overlying aquifer. However, Ebasco's review of this pumping test data revealed that there was significant leakage across this "clay layer" during the pumping test.

The USEPA's Environmental Photographic Information Center (EPIC) produced a report in March 1988 on the ViChem site. The report presents an aerial photographic analysis of the ViChem plant and surrounding area. The first photograph presented was taken in March 1951 and the last was taken in November 1987. A total of 11 photographs are presented.

Among other things, the analysis of the photographs shows areas of "Vegetation Damage" and "Vegetation Stress" along the Blackwater Branch beginning with a September, 1979 photograph. None of the prior photographs show vegetation damage or stress, and all of the later photographs show some vegetation damage and/or stress.

Some of the damaged areas are in the portion of the Blackwater Branch that was inundated with water from the beaver dam. However, the beaver dam was not constructed until some time after April 1985, much later than the first indication of vegetation damage/stress. A topographic base map for the site that was flown in April 1985 shows the Blackwater Branch flowing in its normal channel at that time. It should be pointed out that the damaged/stressed areas are coincident with the contaminated groundwater plume coming off the ViChem site.

In 1988, the USEPA's Environmental Response Branch prepared a bioassessment on the Blackwater Branch and the upper Maurice River. The report concluded that there was an adverse impact to the benthic communities in the Blackwater Branch downstream from the ViChem plant. The impact takes the form of lower species diversity and a toxic response in bioassay tests done with the sediments. The adverse impact on the Maurice River is less, however, probably resulting from dilution. This report is presented as an appendix to the River Areas RI report (Ebasco, 1989c).

1.2.5 Community Concerns

In 1984, after the ViChem site was added to the National Priorities List, EPA implemented a community relations program to inform area residents about the Superfund related activities and obtain their input. Community concern increased from moderate to relatively high and also became more specific. The involvement of organized environmental groups generated media attention and increased public awareness of the site.

As a result of EPA's community relations activities, five major community concerns were identified:

- o Human health risks from exposure to contaminated groundwater because some of the residents relied on groundwater for potable water;
- o Human health risks from exposure to contaminated surface water because local rivers and lakes are used for recreation;
- o Frustration over the perceived lack of remedial action at the site;
- o A perceived lack of cooperation on behalf of ViChem during the remedial response process; and
- o A perception of inadequate information from the NJDEP.

1.3 REMEDIAL INVESTIGATION STUDY

1.3.1 Initial Activities

The initial tasks of this Work Assignment were the development of a Work Plan Memorandum, a Work Plan, and a Field Operations Plan (for both Phase I and II) for the RI/FS. The Work Plan Memorandum presented the scope of the program and the estimated schedule and budget to perform these initial tasks.

Prior to the preparation of project plans, a site walk-through was performed to familiarize the investigators with the site, determine possible sampling locations, and obtain information for developing the Health and Safety Plan. Existing information and prior reports prepared by ViChem and the NJDEP were also reviewed. Following the site visit and the evaluation of the existing data, potential remedial alternatives were identified in order to scope out the field sampling and analyses program and to specify the appropriate levels of data quality required.

1.3.2 Field Investigation

Ebasco's field investigation at the ViChem plant site was conducted in two stages following the initial activities outlined above. The first stage was to conduct a limited site reconnaissance sampling. The second stage involved performing the bulk of the field work described in Section 2 of this RI as a part of the Phase II investigations for the overall ViChem site.

Site Reconnaissance

The site reconnaissance sampling was performed in January, 1987. The purpose of this sampling was to collect selected groundwater samples to determine the type of well construction materials to use on-site, and to collect air samples to establish the level of respiratory protection required during the bulk of the investigation.

The groundwater sampling is described in Subsection 2.2.1. The USEPA determined that if the groundwater samples displayed total organics concentrations of less than 1 mg/l, PVC could be used to construct the monitoring wells. If the total organics concentrations were greater than 1 mg/l, stainless steel would be used to construct the monitoring wells.

The results showed that the total organics concentration in the groundwater was significantly less than 1 mg/l. Therefore, PVC monitoring wells were installed. This resulted in a significant cost savings over using stainless steel.

The air sampling is described in Subsection 2.2.2. The results of the air samples showed that level D respiratory protection could be used by field personnel during the on-site investigations.

Phase II

The Phase II field investigation at the ViChem plant site entailed installing monitoring wells and taking a variety of soil, groundwater and air samples. These investigations are described in detail in Section 2. The methods used to perform the investigations are presented in the approved Field Operations Plan for the site. Prior to commencing these investigations, a number of initial activities were undertaken.

A decontamination pad was constructed. The pad provided an area to steam clean and to collect the decontamination fluids, thus preventing the potential spread of contamination from equipment such as drilling rigs, augers, and drill rods. The pad was constructed on May 5, 1987 in the lagoon area. The location of the pad is presented in Figure 1-5.

The decontamination pad consisted of a plastic lined pit with gravel on top. Heavy equipment was steam cleaned on top of the pad. Water from the steam cleaning percolated through the gravel and was collected in a sump. The sump was pumped dry periodically, with the decontamination water pumped into 55 gallon drums. The drums were stored on pallets in the area shown in Figure 1-5.

Two trailers, an office trailer and an equipment trailer, were brought on-site to facilitate the field investigation. The trailers were installed south of coop #1 and east of coop #2 as shown in Figure 1-5. The trailers were equipped with basic utilities and phone service.

Prior to installing the monitoring wells, the EPA determined the disposition of drill cuttings and well development water that would be generated during the field program. Solid drill

cuttings were to be stored in pits adjacent to the well borings. Drilling fluids, well development water, and well purge water were to be stored in 5,500 gallon liquid tankers.

The pit excavations at each well bore were dug with a backhoe. The excavations were approximately 25 feet long, 3 feet wide, and 5 feet deep. Solid drill cuttings and solids which settled out of the drilling mud were disposed of in the pits. Cement was added to the contents of the pits to stabilize them if necessary. When all of the wells in a cluster were completed, the pits were graded such that no mound was left around the well bore. The pit excavations were all shallow enough to be in the unsaturated zone, and were installed downgradient of the monitoring wells as best as practical.

A total of four 5,500 gallon tanks were procured for the field investigation. Two of these tanks were filled with well development water and excess drilling mud. The other two tankers were filled with water purged from the monitoring wells prior to sampling. One tanker was filled with purge water from each of the two rounds of groundwater samples.

The tankers were staged in the ViChem parking lot as shown in Figure 1-5. The tankers remained stationary during the investigation. Well development and purge water was containerized at the well head into 55-gallon drums. The drums were then transported on the back of pick-up trucks to the parking lot and the contents were pumped into the tankers.

At the end of the field investigation, the liquids in the tankers were disposed off-site. The tankers were driven by a licensed transporter to a licensed off-site treatment facility. The contents were then treated prior to disposal.

An access agreement was entered into with ViChem prior to conducting the field investigation at the plant site. Among other things, this agreement required Ebasco to give three days notice to ViChem prior to conducting any activities on-site. Schedules were provided to ViChem personnel throughout the duration of the on-site activities.

Monitoring well permits were obtained prior to installing the monitoring wells. The permits were obtained from the NJDEP Division of Water Resources.

After the initial field activities, the field investigation at the ViChem plant site took place. The investigation lasted from May, 1987 through the end of September, 1987. The investigation at the plant site consisted of the following major work elements:

- o Conduct a surface geophysical investigation;

- o Install 36 groundwater monitoring wells; eight deep wells approximately 100 to 120 feet deep, 14 intermediate wells approximately 40 to 70 feet deep, and 14 shallow wells approximately 25 feet deep;
- o Obtain surface soil samples from approximately 98 locations on a soil sampling grid;
- o Sample soils from approximately 25 soil borings on the soil sampling grid to the top of the water table;
- o Sample soils from five borings inside of building #9, where crystalline arsenic wastes were reportedly observed on the ground in the past;
- o Obtain one sample of the dust inside each of the four chicken coops on site which had reportedly been used to store waste and/or raw materials in the past;
- o Obtain samples of the water in the lined and unlined lagoons, and obtain samples of the sediment from one unlined lagoon on site;
- o Obtain surface soil samples from 13 off-site locations, some of them adjacent to the ViChem plant;
- o Obtain two rounds of groundwater samples from the 36 Ebasco installed monitoring wells and the 11 existing ViChem monitoring wells;
- o Obtain treatability samples from contaminated groundwater and soil on site; and
- o Conduct various physical tests and measurements to determine the hydraulic properties of the aquifers underneath the ViChem site.

A total of approximately 1,554 samples were sent to CLP laboratories from the ViChem plant site area, along with approximately 71 duplicate samples (approximately 5%). Table 1-3 provides a breakdown of the numbers and types of analyses performed in the field investigation.

1.3.3 Bench-Scale Treatability Studies

Bench-scale treatability studies were performed to evaluate the feasibility of using several different treatment methodologies to treat arsenic contaminated soil and groundwater.

A soil fixation treatability study was performed to determine if arsenic could be chemically stabilized or physically bound to the soil such that total arsenic concentration in the leachates from the RCRA EP Toxicity test and the Multiple Extraction

TABLE 1-3
CLP SAMPLE AND ANALYSIS SUMMARY

MEDIUM SAMPLED	# OF LOCATION	ARSENIC DISSOLVED	ARSENIC TOTAL	ASFE	ATTLIM	EPTOX	NUMBER OF SAMPLES GRNSZE	BNA	HSLINO	HSLVOA	PERM	P/PCB	RESDUS	TOC	TODUS	TOTAL
<u>SOIL</u>																
SURFACE SOIL	98		87					25	25	32		25				194
SOIL BORING	25		81			2		29	29	29		29				199
WELL BORING	14		186		4		31	37	37	37	4	37				373
BLDG. BORING	5		15			2		11	11	11		11				61
OFF-SITE	16		17													17
BENTONITE	1		1													1
DRILL SAND	1		1													1
<u>COOP DUST</u>	4								5							5
<u>SEDIMENT LAGOON</u>	6			6		1	6	1						6		18
<u>WATER</u>																
LAGOON	6	7						7	7	7		7				35
GRND WATER 1	54	50						13	50	50		50				213
GRND WATER 2	55	54						15	54	54		54				231
DRILL WATER	3	3														3
DRILL MUD	22	25														25
<u>AIR</u>	45												15		15	45
<u>FIELD BANK</u>	30	7	8					20	24	24		24				107
<u>TRIP BLANK</u>	26									26						26
	118		439	6	4	5	37	157	242	270	4	237	15	5	15	1554

Key: ASFE: Arsenic and Iron
 ATTLIM: Atterberg Limits
 EPTOX: EP Toxicity
 GRNSZE: Grain Size
 BNA: HSL Extractables-BNA Fraction
 HSLINO: HSL Inorganics
 HSLVOA: HSL Volatiles
 PERM: Permeability
 P/PCB: Pesticides/PCBs
 RESDUS: Respirable Dust
 TOC: Total Organic Carbon
 TODUS: Total Dust

TABLE 1-3 (Cont'd)
CLP SAMPLE AND ANALYSIS SUMMARY

MEDIUM SAMPLED	# OF LOCATION	ARSENIC DISSOLVED	TOTAL	ASFE	ATTLIM	EPTOX	GRNSZE	NUMBER OF SAMPLES BNA	HSLINO	HSLVOA	PERM	P/PCB	RESDUS	TOC	TODUS	TOTAL
SOIL																
SURFACE SOIL			3					2	2	3		2				12
SOIL BORING			5					1	1	1		1				9
WELL BORING			7					1	1	1		1				11
BLDG. BORING																
OFF-SITE			1													1
BENTONITE																
DRILL SAND																
COOP DUST									1							1
SEDIMENT LAGOON																
WATER																
LAGOON		1						1	1	1		1				5
GRND. WATER 1		2						1	2	2		2				9
GRND. WATER 2		5						2	5	5		5				22
DRILL WATER																
DRILL MUD			1													1
		8	17					8	13	13		12				71

Key: ASFE: Arsenic and Iron
 ATTLIM: Atterberg Limits
 EPTOX: EP Toxicity
 GRNSZE: Grain Size
 BNA: HSL Extractables-BNA Fraction
 HSLINO: HSL Inorganics
 HSLVOA: HSL Volatiles
 PERM: Permeability
 P/PCB: Pesticides/PCBs
 RESDUS: Respirable Dust
 TOC: Total Organic Carbon
 TODUS: Total Dust

Procedure (MEP) test were less than 5.0 mg/l. Also, the Unconfined Compressive Strength of the fixed product was designed to be at least 1,500 lb/ft². These tests are described in Section 7.1.

A soil extraction treatability study was performed to determine if arsenic could be removed from the soils to a concentration below 20 mg/kg. The target level of 20 mg/kg total arsenic was established at the inception of the study based on the New Jersey Environmental Cleanup Responsibility Act (ECRA) guidance for arsenic in soils. The extraction tests are described in Section 7.2.

The target levels for the soil treatability studies, fixating the soils such that the leachable arsenic concentration was less than 5 mg/l and extracting arsenic such that the remaining arsenic concentration was less than 20 mg/kg, were established at the beginning of the study. It was believed that if these levels were achieved, the treated soils would be suitable for disposal in a nonhazardous waste landfill. Subsequently, guidance has been received from EPA Region II, EPA Headquarters, and the NJDEP on the criteria for nonhazardous waste disposal of the treated soils. This is dealt with in detail in the ViChem Plant Site FS report (Ebasco, 1989b).

Three treatment methods were evaluated for removing arsenic from the groundwater to a concentration of 0.05 mg/l, the Federal Safe Drinking Water Act standard for arsenic in drinking water. The treatment technologies included adsorption of arsenic using activated aluminum and titanium oxides, ion-exchange using two resins, and reverse osmosis using a polyamide and a cellulose acetate membrane. If successful, the treatment technologies could be used as a final polishing step to lower the discharge concentration to 0.05 ug/l or less after pre-treatment to remove the bulk of the arsenic. This would be necessary before pump and treat scenarios could be evaluated for groundwater cleanup. The groundwater treatability tests are presented in Sections 7.3, 7.4, and 7.5.

1.3.4 Risk Assessment

A risk assessment was performed using the basic methodology described in the Superfund Public Health Evaluation Manual, (USEPA, 1986b). Data from field sampling were used to evaluate exposure estimates for local residents and workers on-site. Exposure pathways and assumptions used are described in detail in Section 6.3.

1.4 OVERVIEW OF THE REMEDIAL INVESTIGATION REPORT

This RI report is comprised of eight sections. The Introduction, Section 1.0, provides background information regarding site location and physiography, facility history and operation, waste discharges, and community concerns. The nature and extent of the

problem, as identified through previous studies, is presented in this section. A summary of the RI, identifying the activities of each major component is also provided.

Section 2.0, Study Area Investigations, provides a detailed description of the ViChem plant site field investigation and provides general information of the demography, land use, climatology and cultural resources in the vicinity of the plant site.

Section 3.0, Physical Characteristics of the Study Area, provides a discussion of the site geology including the stratigraphy and structure, and provides a description of the site hydrogeology including aquifer characteristics and a water balance. The results of the geophysical investigation are also presented.

Section 4.0, Nature and Extent of Contamination, describes the types and the levels of contaminants found in the various media sampled during the RI.

Section 5.0, Contaminant Fate and Transport, describes the geochemistry and other factors which influence the movement of the main contaminants found at the ViChem plant site.

Section 6.0, Risk Assessment, presents the risks calculated for various scenarios of exposure to the air, soil, and groundwater in the vicinity of the ViChem plant site, and provides a brief environmental assessment.

Section 7.0, Bench-Scale Treatment Studies, presents the results of the treatability studies performed on the soil and groundwater.

Section 8.0, Summary and Conclusions, presents a brief summary of each major component of the RI, discusses the limitations of the data, recommendations for future work, and recommends remedial response objectives.

This report contains 12 appendices:

Appendix A presents the chemical analytical data from Ebasco's field investigations at the site.

Appendix B presents boring logs from monitoring wells.

Appendix C presents boring logs from the soil borings.

Appendix D presents monitoring well construction sheets for the wells installed for this RI.

Appendix E presents the pumping test analysis from pumping ViChem monitoring well MW-10.

Appendix F presents groundwater velocity calculations for the one-dimensional groundwater transport model.

Appendix G presents laboratory results of the soil extraction treatability studies.

Appendix H presents laboratory results for the soil fixation treatability studies.

Appendix I presents laboratory results for the groundwater treatability studies.

Appendix J presents toxicological profiles for the indicator chemicals modeled in this Risk Assessment.

Appendix K presents the water balance calculations.

Appendix L presents available boring logs and well construction details for ViChem's monitoring and production well.

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2.0 STUDY AREA INVESTIGATIONS

2.1 SITE FEATURES INVESTIGATION

This section presents the site features investigation for the ViChem plant site. General site demography, land use, natural resources, climatology and cultural resources are presented below, while detailed geologic and hydrogeologic data are included in Section 3.0.

2.1.1 Demography

The ViChem site is located in the City of Vineland, Cumberland County, New Jersey. Vineland is the largest city within the Vineland-Millville-Bridgeton Primary Metropolitan Statistical Area (PMSA), which is part of the Philadelphia-Wilmington-Trenton Standard Metropolitan Statistical Area (SMSA).

The city encompasses a total of 69.5 square miles and has a population of 53,753 (U.S. Bureau of the Census, 1980). This number represents a 13.4% increase in population over the 1970 census data. According to projections by the Cumberland County Department of Planning and Development, the population of Cumberland County as a whole (132,866, U.S. Bureau of the Census, 1980) is expected to increase by approximately 14% to 151,500 by the year 2000. Projections based on this rate of growth for Cumberland County indicate that the population of Vineland will reach 61,278 by the year 2000.

The site itself is situated in an industrial area in the northwest sector of the City of Vineland. It encompasses approximately 24 acres and is surrounded by residential, agricultural and woodland zones.

The site is located within census tract 409, which encompasses 9,781.7 acres, and contains 8,921 residents. The site is immediately adjacent to census tract 404, which encompasses 1352.8 acres, and contains 5,962 residents, and within one mile of census tract 401 (which encompasses 233.7 acres and contains 525 residents) and census tract 402 (which encompasses 553.4 acres, and contains 6,244 residents). Total 1980 population within these four census tracts is 21,652 residents.

2.1.2 Land Use

The City of Vineland is classified as an urbanized area by the New Jersey Division of State and Regional Planning. Approximately 72% of the city's land is undeveloped. The remaining 28% is devoted to residential development (11.5%), commercial development (1.9%), industrial uses (3.7%), public and semi-public facilities (3.6%), open space (0.9%), and streets and highways (6.4%). Vineland lies on essentially a level

sloping from northwest to southeast with topographic variations from 20 to 120 feet above mean sea level (MSL).

The ViChem site is located in the northwest sector of the City of Vineland and is situated entirely within a designated I-2 (General Industrial) zone. The site is bordered on the northeast, east and south by an R-3 (medium to low density Residential) zone, on the north by an A (Agricultural) zone, and on the west by North Mill Road and a W (Woodlands) zone.

The Blackwater Branch of the Maurice River flows northeast to southwest, in proximity to, and partially through, the site itself. Soils in the general area of the site are alluvial.

Lands immediately adjacent to the Blackwater Branch constitute a floodplain which extends the entire length of the tributary to the Maurice River. According to officials of the City of Vineland, the Blackwater Branch is not currently used for recreational purposes. A city park is located approximately one-half mile downstream of the confluence of the Blackwater Branch and the Maurice River at the Almond Road bridge. The swimming area here was closed by the NJDEP as a result of arsenic contamination but was reopened in June, 1988 after the NJDEP performed a risk assessment and determined that the potential health risks from using the beach were acceptable.

The area around the site is seen by the City of Vineland as having limited potential for future residential development. However, commercial/industrial development is expected to increase in the near future. A major catalyst for future commercial/industrial development in this area will be the completion of NJ State Route 55. This major interstate arterial is located near the western border of Vineland and will connect the Vineland-Millville area with the Philadelphia-Camden region. Construction is expected to be completed in 1989 and corridor-type commercial/industrial development is expected to follow. Conversations with Vineland officials indicate that the city has received proposals from out-of-state and local developers for major commercial/warehouse projects within the Route 55 corridor.

The city is currently served by NJ Route 47, and secondary routes 555, 540, and 552. These routes connect with other major and minor arterials in, and near, Vineland to provide surface transportation links to other major north-south and east-west transportation corridors.

Rail service in the area is provided by Conrail and is limited to freight service only. Local air service is provided by the Millville Municipal Airport in Millville, approximately 10 miles to the south.

2.1.3 Climatology

Available climatological data were obtained from cooperative weather stations, maintained by the National Weather Service, located in Vineland (precipitation and wind) and Bridgeton (temperature). The Vineland station had accumulated data since 1885, while the Bridgeton station had data dating back to 1894.

Vineland receives approximately 45 inches of rainfall per year. Monthly averages range from 3.46 inches in April, to 5.21 inches in August. During an average year, Vineland can expect 77 days when precipitation will exceed 0.1 inches, with 30 of those days exceeding 0.5 inches. Mean snowfall amounts to 18.6 inches with the maximum occurring in February (6.4 inches).

No temperature data are available for Vineland proper, but Bridgeton (12 miles WSW of Vineland) exhibits a mean annual temperature of 54.7 degrees Fahrenheit (12.6°C). The mean maximum and minimum annual temperatures are 65.0 and 44.6 degrees Fahrenheit (18.3°C and 7.0°C), respectively. The highest temperature recorded was 104 degrees Fahrenheit (40.0°C), and the lowest temperature was -12 degrees Fahrenheit (-24.4°C). The average growing season is 170 days and the average dates of the last and first killing frosts are April 15 and October 25, respectively.

Although detailed wind information is not available for the site, from October through April the predominant wind flow is from the northwest. From May through August the dominant flow is out of the southwest, and during September the wind is from the southeast.

2.1.4 Cultural Resources

Conversation with officials from the City of Vineland, Cumberland County and the Vineland Historical and Antiquarian Society indicate there are no significant cultural resources in the immediate vicinity of the ViChem site.

2.2 SITE RECONNAISSANCE INVESTIGATION

The site reconnaissance investigation was performed in December, 1986. The purpose of the investigation was to collect ground-water samples to determine whether to use PVC or stainless steel well construction materials, and to collect air samples to establish the level of respiratory protection to use during the bulk of the field work at the plant site. The site reconnaissance preceded the field work described in the later sections.

2.2.1 Groundwater Sampling

2.2.1.1 Sample Locations and Methods

Groundwater samples were collected from six existing monitoring wells, MW-1, MW-3, MW-6, MW-7, MW-8 and MW-11. These wells were selected to provide coverage of the presumed contaminated areas. These wells are shown in Figure 2-1.

The groundwater samples were obtained after purging three well volumes from each well. Purging was performed by bailing, or by pumping with a surface suction pump. When a suction pump was used, the intake line was made of ASTM-D2239 PVC and had a one-way check valve on the end. Purge water was containerized in a 55-gallon drum for each well.

The groundwater samples were analyzed for HSL (Hazardous Substance List) organics, inorganics, chloride and dissolved arsenic. The dissolved arsenic aliquot was filtered in the field through a disposable filter with 0.45 um pores. This aliquot and the unfiltered aliquot analyzed for HSL inorganics were preserved in the field with nitric acid of pH less than 2. All sample aliquots were iced prior to shipment.

2.2.1.2 Results and Conclusions

The analytical results of the monitoring well samples are presented in Section I of Appendix A. All of the groundwater samples from the six monitoring wells displayed total organics concentrations of less than 1 ppm. Therefore, the USEPA decided to use PVC monitoring well construction materials during the monitoring well installation program.

2.2.2 Air Sampling

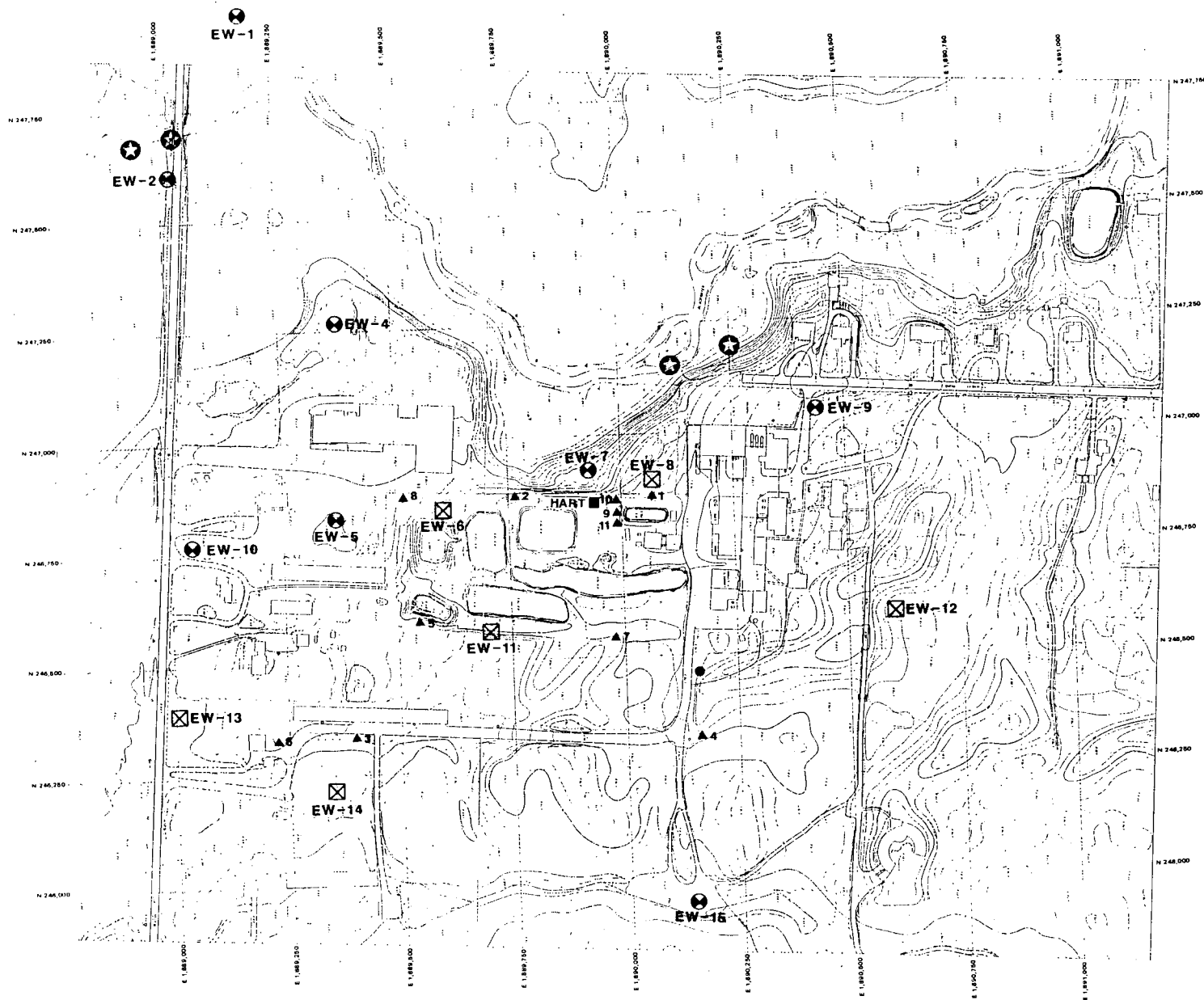
Air sampling was performed to determine what contaminants were present in the air in and around the ViChem plant site and at what concentrations. The data would serve to help determine the potential for exposure during other activities and thereby provide a base to establish the levels of protection (A, B, C, D) for on-site personnel.

On December 4 and 5, 1986, samples were collected at six locations for EPA Volatile Organic Priority Pollutants. On December 9 and 12, 1986, 8-hour samples were collected at the same locations for total and respirable particulates and total arsenic.

2.2.2.1 Sample Locations and Methods

The air sampling locations were chosen on the basis of their proximity to suspected "hot spots" or, in one case, with respect to providing an indicator of background concentrations. The six locations (see Figure 2-2) are:

VIN 001 0925



- ⊗ TRIPLE WELL CLUSTER (8)
- ⊠ DOUBLE WELL CLUSTER (6)
- ★ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART (1)

0 100 200 300
SCALE IN FEET

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF
ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1993

U.S. ENVIRONMENTAL PROTECTION
AGENCY

VINELAND CHEMICAL COMPANY SITE

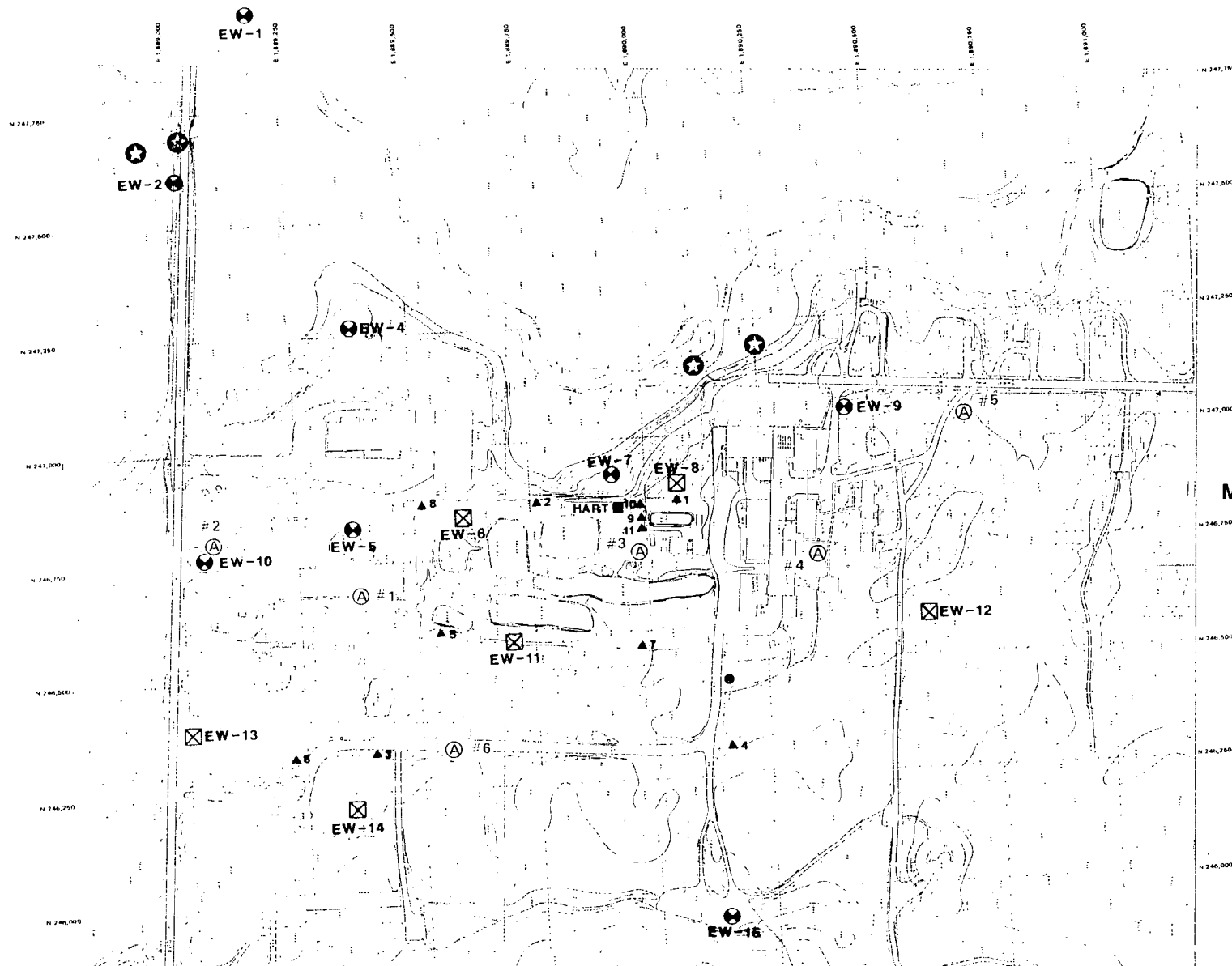
FIGURE 2-1

MONITORING WELL LOCATIONS

EBASCO SERVICES INCORPORATED

VIN 001 0925

VIN 001 0926



MONITORING WELL LOCATIONS

- (A) '86 AIR SAMPLING LOCATIONS
- ⊗ TRIPLE WELL CLUSTER (8)
- ⊠ DOUBLE WELL CLUSTER (6)
- ★ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 2-2 SITE RECONNAISSANCE AIR SAMPLING LOCATIONS
EBASCO SERVICES INCORPORATED

VIN 001 0926

Station 01 - By second door west of SE corner of old chicken coop, in proposed support of trailer area.

Station 02 - 100 feet north and 100 feet east of utility pole #VE4741 adjacent to Mill Road.

Station 03 - Approximately 200 feet west of treatment building.

Station 04 - Approximately 100 feet north of building number 7, along walkway.

Station 05 - Approximately 50 feet south of plant's east exit to Wheat Road.

Station 06 - Approximately 50 feet west of SE corner of chicken coop/storage building located on road at the south entrance to plant from Mill Road.

Sampling methods used were standard industrial hygiene techniques and are described in detail in the approved Field Operations Plan.

Sampling pumps capable of maintaining the flow rates within $\pm 5\%$ of the calibrated rates were used to collect the samples. Sampling pumps were calibrated prior to and after each sampling period to determine the average flow rate over the duration of the sampling.

Sampling media used included Tenax and Tenax/Carbon sorption tubes for collecting EPA Volatile Organic Priority Pollutants, 0.8 micron mixed cellulose ester filter cassettes for arsenic, PVC filter cassettes for total particulates, and PVC filter/10 mm nylon cyclone for respirable particulates.

The Tenax and Tenax/charcoal tubes were analyzed utilizing thermal desorption followed by using a Zeeman 3030 graphite furnace, whereas the respirable and total particulate samples were analyzed gravimetrically on a microbalance.

2.2.2.2 Sample Results and Conclusion

Twenty-eight samples were analyzed for EPA Volatile Organic Priority Pollutants. Results indicate two classes of organic air pollutants are present.

The first class is normal emissions from internal combustion engines. Benzene, toluene, ethylbenzene and the xylenes were detected in the parts-per-billion range, which is normal for ambient background levels.

The second class is chlorinated solvents. Chloroform, 1,1,1-trichloroethane, carbon tetrachloride, trichloroethene and tetrachlorethene were detected in the very low parts-per-billion

range. While these compounds would not be expected in a rural location, their concentrations are so low that they would not pose a health risk to on-site workers.

Fourteen samples were collected and analyzed for arsenic, respirable dusts and total dusts. Total particulates and respirable particulates were detected at the limits of detection, and averaged approximately 0.001 mg/m³. Arsenic was not detected above the minimum detection level of 1 ug/m³.

These sample results confirmed that the exposure pathway for ordinary on-site activities would be low and that level D respiratory protection would be appropriate for most on-site activities. It was determined that real-time monitors such as the HNU would be used during subsequent investigative activities, supported by additional sampling for the contaminants of concern.

2.3 GEOPHYSICAL INVESTIGATIONS

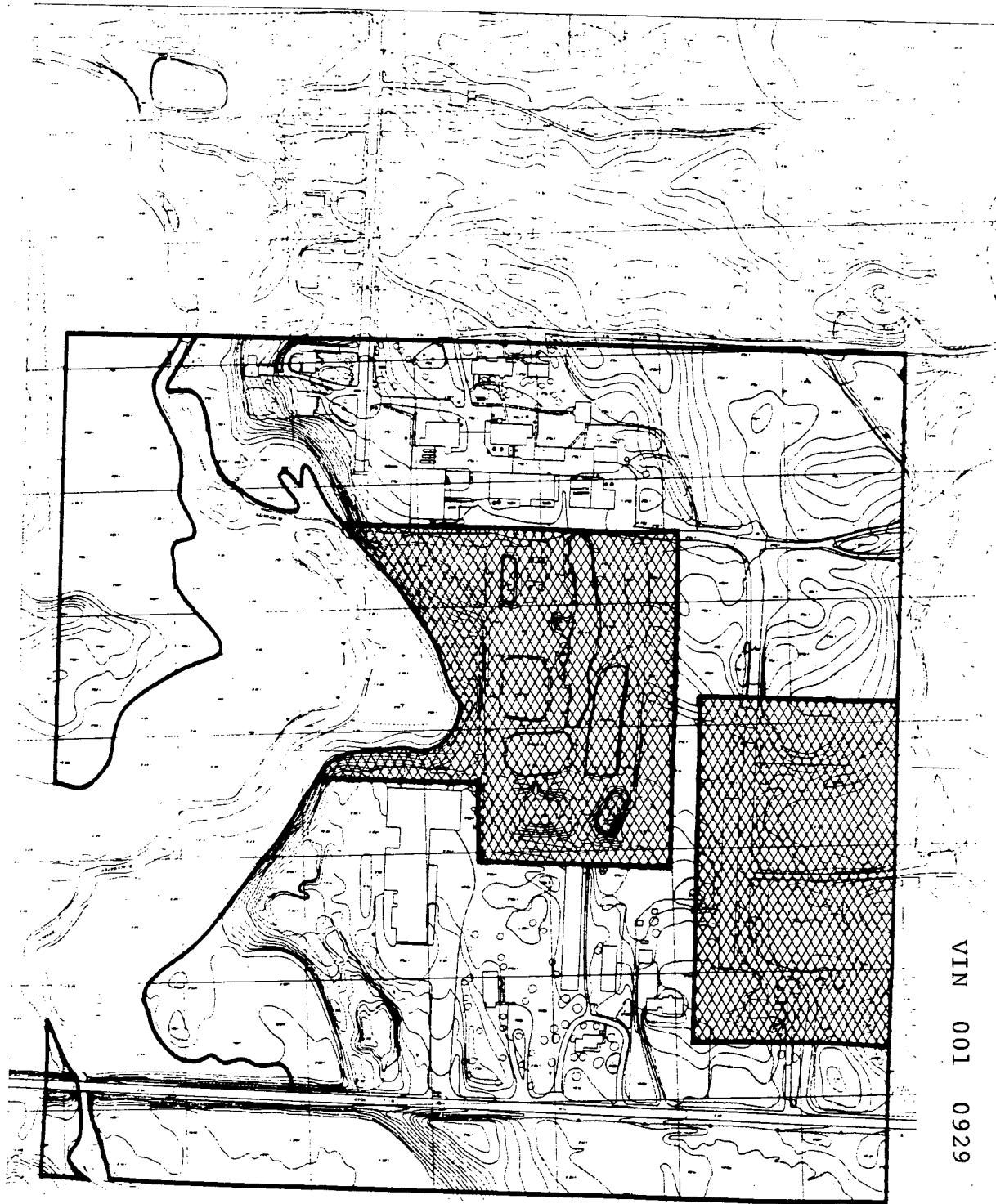
Geophysical investigations at the plant site consisted of a detailed terrain conductivity survey, resistivity soundings at selected locations, and electromagnetic screening for metallic objects at planned drilling locations. Initial investigations including terrain conductivity profiling and resistivity soundings were conducted in December 1986. Follow-up investigations were carried out in February 1987. The objective of the initial phase was a preliminary determination of the probable extent of contaminants (primarily arsenic waste salts). The follow-up investigations were directed towards evaluating potential drilling sites for the presence of metal (i.e., metal drums) which might complicate drilling operations and/or create safety hazards if encountered. The results of the geophysical survey are presented in Section 3.0. The field methods used were standard methods and can be found in the approved FOP for the site.

2.3.1 Survey Locations

The area encompassed by the geophysical survey is shown in Figure 2-3. A total area of 1,700 by 1,700 feet was surveyed. The majority of the area was surveyed on a 100-foot grid. Two areas of suspected high contamination were surveyed on a 50-foot grid. These were the lagoon area north to the Blackwater Branch, and south of the former outdoor storage area. In addition, soundings were conducted at potential drilling sites.

The presence of buildings, power lines, underground cables and other cultural features may interfere with the electrical and magnetic fields being detected by the geophysical instruments. Therefore the total survey area was broken up into 7 subareas, shown in Figure 2-4.

VIN 001 0928



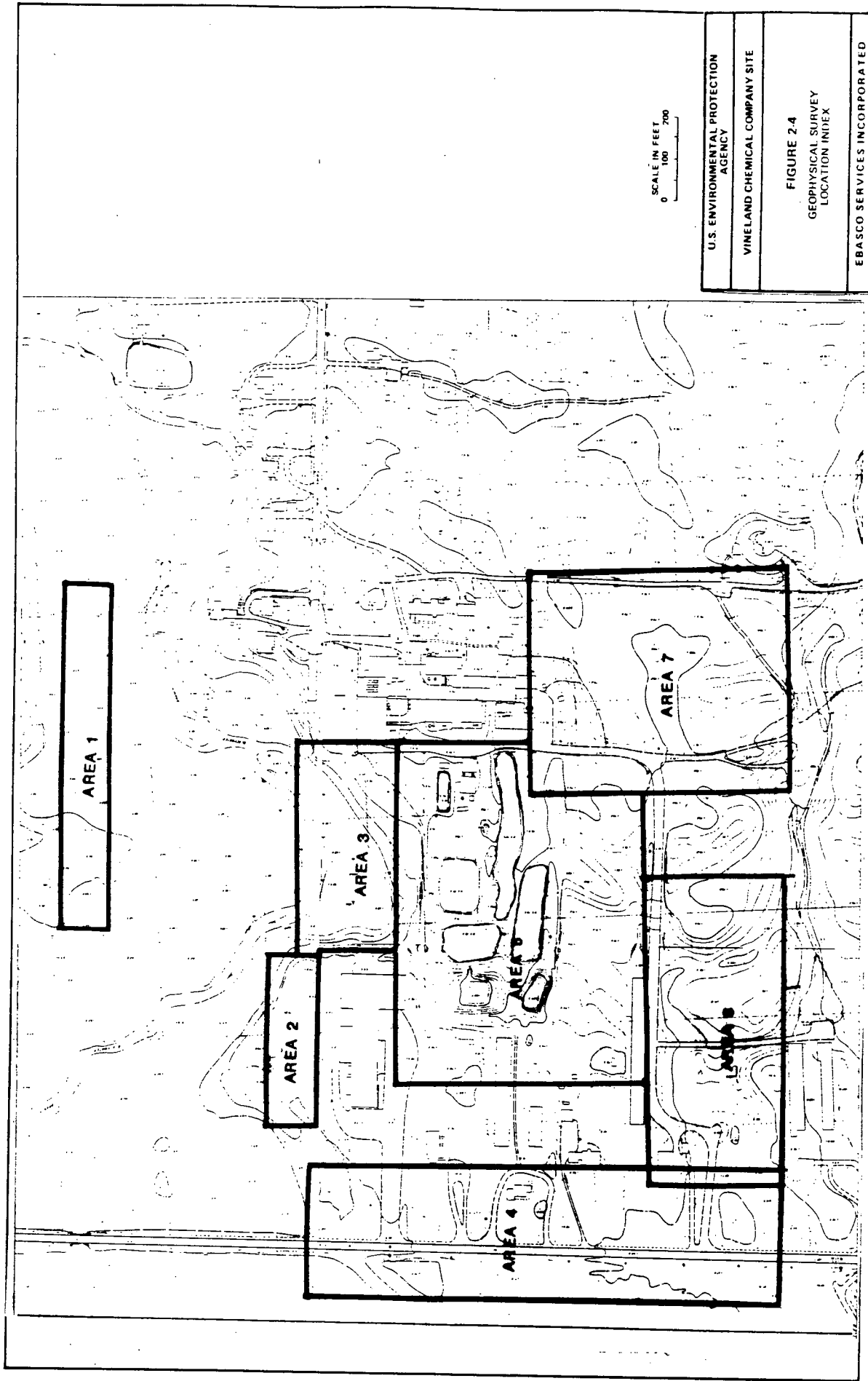
50 FOOT GRID

100 FOOT GRID

SCALE IN FEET
0 100 200

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 2-3 GEOPHYSICAL SURVEY GRIDS
FRASCO SERVICES INCORPORATED

VIN 001 0929



2.3.2 Survey Methods

Electromagnetic conductivity surveys (EM) and electrical resistivity surveys are commonly implemented to characterize the variable nature of subsurface electrical properties at a given site. Such variations are associated with lateral and vertical changes in geology or groundwater chemistry (usually by the introduction of wastes or salt-water intrusion), the presence of buried objects (usually metallic), and to a lesser extent changes in the depth to groundwater table.

Electromagnetic terrain conductivity profiling was performed by inducing an electromagnetic field into the ground via a transmitter coil. This field generates a secondary magnetic field which is detected by a receiver coil and then transformed into an output voltage. The magnitude of this voltage is linearly related to the ground's conductivity.

Resistivity soundings were performed using a Schlumberger sounding array, whereby a current is introduced into the ground at two current electrodes, and the resulting voltage drop is measured at two potential electrodes. For soundings, the location of the center of the array was held constant, while the spacing of the current and potential electrodes was progressively increased to determine the variation in resistivity with depth.

Initial electromagnetic terrain conductivity profiling was performed using a Geonics, Ltd. EM34-XL Terrain Conductivity Meter. With this instrument, the maximum response depth (depth which has the strongest influence upon the instrument's total signal) can be targeted by varying the coil orientation. When using the instrument in the horizontal-dipole mode, measurement of the near surface conductivity is enhanced. This type of survey is used for relatively shallow, near surface exploration. When somewhat deeper zones are to be evaluated, the vertical-dipole mode is implemented. In this mode, the material at a depth of about 0.4 times the coil separation contributes most to the total observed signal. While both coil orientations were used at each occupied data station for the entire survey, the data collected using the horizontal-dipole mode appeared unremarkable, suggesting that at least in the near surface the highly permeable sands at the site may have been flushed of arsenic salts by surface recharge.

Three vertical electrical soundings (VES) were performed. Two of the soundings were located at potentially contaminated (as suggested by the EM34-XL survey) areas while the other soundings were located in an area interpreted as representing apparent background conductivity conditions.

VIN 001 0931

2.4 SOILS INVESTIGATION

A variety of soil samples were taken during the investigation. Surface soil samples were collected and soil borings were conducted on high density (100 feet by 100 feet) and low density (200 feet by 200 feet) sampling grids. Soil samples were taken from monitoring well borings during drilling. Soil samples were also obtained from off-site and residential areas adjacent to the site, from underneath one of the manufacturing buildings (building #9) and in some of the lagoons. Each of these is described in detail in Sections II, III, and IV of the following sections. The analytical results are presented in Appendix A. The field methods used were standard methods and can be found in the approved FOP for the site.

2.4.1 Surface Soil Investigation

A soil sampling grid was established. High density sampling on a 100 by 100 foot grid was conducted in areas of known or suspected contamination. This included the lagoon area, the manufacturing area, the former outdoor storage area by well cluster EW-14, the area north of the lagoons to the Blackwater Branch, and an area approximately 100 feet from both sides of the plant road. Low density sampling was conducted on a 200 by 200 foot grid on the site property. The soil sampling grid is shown in Figure 2-5. The total number of analyses performed on the surface soil samples is presented in Table 2-1. The analytical results are presented in Section II of Appendix A.

2.4.1.1 Sample Locations

Sixty-seven surface soil sampling nodes are located on the high density 100 foot sampling grid shown in Figure 2-5. Surface soil samples from 0 to 2 feet were taken at these 67 locations. Subsurface soil samples were taken by conducting borings to the water table at 19 locations. To establish the matrix variability of the surface soils, colocated samples were obtained at five of the sampling sites. Subsurface matrix variability was established by taking samples from the monitoring well borings.

Thirty-one surface soil sampling nodes are located on the low density sampling grid comprising the site periphery. Surface soil samples from 0 to 2 feet were taken at these 31 locations. Subsurface samples were obtained by conducting borings at six locations. Surface soil matrix variability was established by obtaining four colocated surface soil samples, while subsurface soil matrix variability was established by taking samples from monitoring well borings.

VIN 001 0932

2.4.1.2 Sample Methods

One sample from 0 to 2 feet was obtained from each sampling site. Any organic matter at the surface such as grass was removed before the sample was taken. A six inch long stainless steel hand auger was rotated down to two feet through four 6 inch intervals. The four intervals were emptied into a decontaminated stainless steel beaker, where the soil was homogenized before being placed in sample jars. Samples for volatile analyses were taken from the stainless steel beaker before homogenizing. Seventy-five percent of the soil samples were analyzed for total arsenic only and the remaining 25% were analyzed for HSL organics/inorganics (+30). All analyses were performed by a CLP laboratory. Samples for HSL pollutant analyses were selected randomly.

2.4.2 Off-Site Soils Investigation

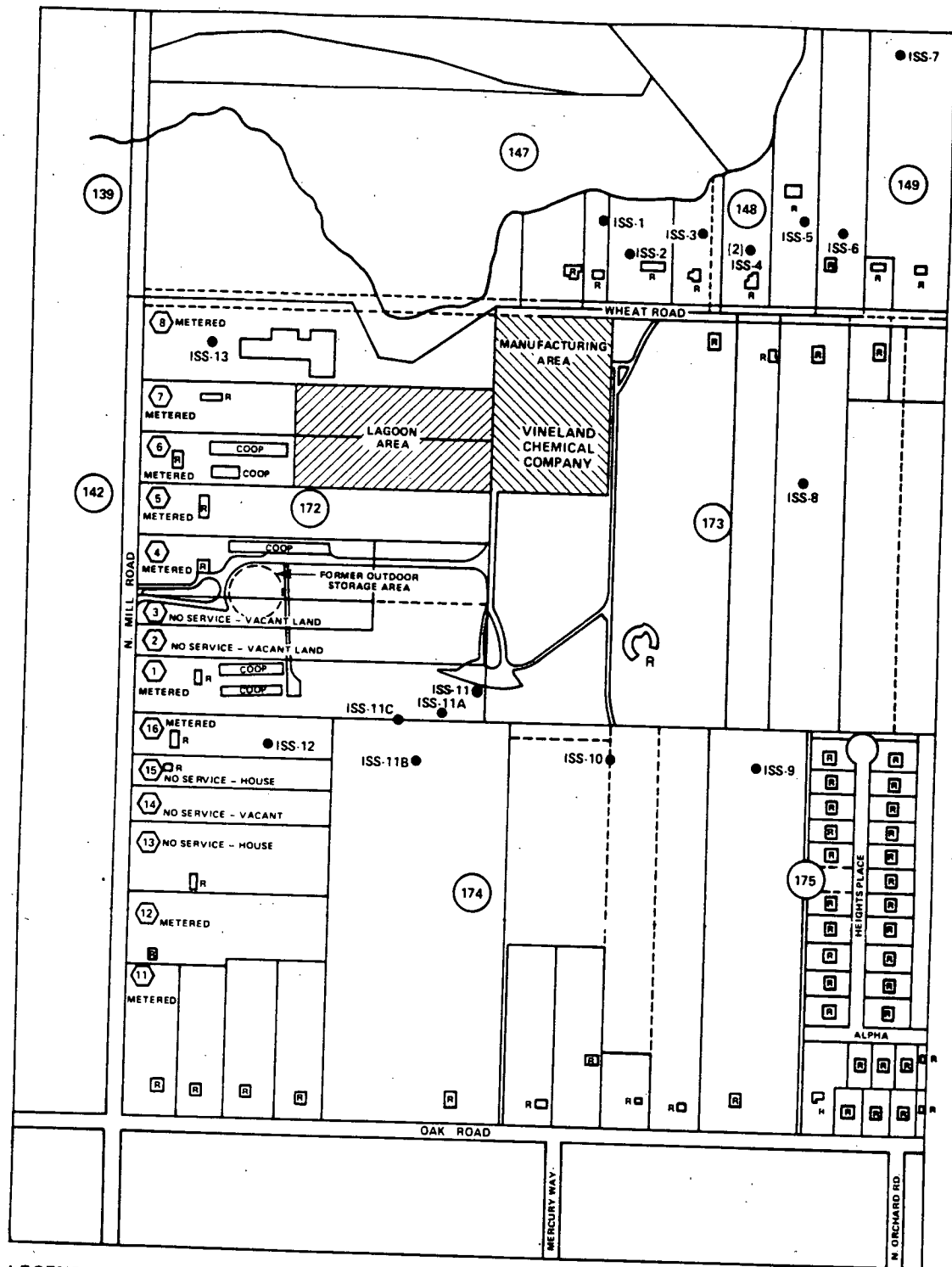
2.4.2.1 Sample Locations

Surface soil samples were obtained from 13 off-site locations; seven from residences along Wheat Road and six from residences or undeveloped woodlands along the eastern, western and southern boundaries of the ViChem property. These locations are shown in Figure 2-6. These samples were taken to address the possible off-site, windblown, migration of contaminated soil from the ViChem plant grounds. The analyses on these samples are presented in Table 2-2 with the results presented in Table 4-4.

As discussed in Section 4.0, one of the off-site soil samples (ISS-11) displayed an elevated arsenic concentration (78 mg/kg). As shown in Figure 2-6, this sample was obtained close to the clearing at the southern end of the property where surface soils stripped from the manufacturing area were dumped previously. This location was resampled in November, 1988 at locations ISS-11A, -11B, and -11C shown in Figure 2-6. These locations are all in undeveloped woodlands, and all had low arsenic concentrations (see Table 4-4).

2.4.2.2 Sample Methods

The off-site soil samples were taken from 0 to 6 inches. The samples were obtained with a stainless steel hand auger and homogenized in a stainless steel beaker before being placed in sample jars. Any grass or other organic matter on the surface was removed before the soil samples were collected. The soil samples were analyzed for total arsenic only by a CLP laboratory.



LEGEND:

- 172 BLOCK NUMBER
- SOIL SAMPLING LOCATIONS
- R RESIDENCES
- 1 LOT NUMBER



0 200 400 600 800
SCALE IN FEET

BASE MAP PREPARED BY CITY ENGINEER, WILLIAM G. AUSTIN, CITY OF VINELAND, OCTOBER 1971.

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 2-6 RESIDENTIAL SOIL SAMPLING LOCATIONS AND WATER SUPPLY ALONG N. MILL ROAD
EBASCO SERVICES INCORPORATED

VIN 001 0936

TABLE 2-2

NUMBER OF OFF-SITE SURFACE SOILS

STATION NUMBER	MEDIUM	TOTAL ARSENIC
ISS-1	Soil	1
ISS-2	Soil	1
ISS-3	Soil	1
ISS-4	Soil	1
ISS-5	Soil	1
ISS-6	Soil	1
ISS-7	Soil	1
ISS-8	Soil	1
ISS-9	Soil	1
ISS-10	Soil	1
ISS-11	Soil	1
ISS-11A	Soil	1
ISS-11B	Soil	1
ISS-11C	Soil	1
ISS-12	Soil	1
ISS-13	Soil	2*

17

* Duplicate analysis

2.4.3 Subsurface Soil Investigation

2.4.3.1 Soil Borings

2.4.3.1.1 Sample Locations

Subsurface soil samples were collected by conducting borings to the water table at 25 locations in the soil grid area. Subsurface soil matrix variability was established by taking samples from monitoring well borings. Some of the boring nodes were established before going into the field based on known past operating practices and suspected areas of contamination. Certain boring locations were sited based on results of the geophysical survey. The borings were placed as close to the sampling grid nodes as accessible to the drilling rig. The soil boring logs are found in Appendix C, with the analytical results presented in Section IV of Appendix A. The total number of analyses performed on the soil boring samples is presented in Table 2-3.

2.4.3.1.2 Sample Methods

The soil borings were sampled by advancing two foot carbon steel split spoons continuously until the water table was reached (0 to 2 feet; 2 to 4 feet; 4 to 6 feet; 8 to 10 feet; etc). It was not necessary to advance the augers because the holes from the split spoon samples stayed open to the water table. The contents of the split spoons were homogenized in stainless steel beakers before being placed in sample jars. The numbers of samples from each boring varied depending on the depth to the water table which ranged from approximately 5 to 15 feet below ground. Seventy-five percent of the soil samples were analyzed for total arsenic and the remaining 25% were analyzed for HSL organics/inorganics (+30). All analyses were performed by a CLP laboratory. Samples for HSL pollutant analyses were selected randomly.

2.4.3.2 Monitoring Well Soil Samples

2.4.3.2.1 Sample Locations

The Phase II monitoring well program was designed to delineate the contaminant plume and provide a data base for the FS. Figure 2-1 presented the Phase II monitoring well locations, while Table 2-4 summarizes the actual depths and screened intervals. The details of the monitoring well construction are presented in Subsection 2.5.2. Appendix B presents the monitoring well boring logs, while the total number of analyses performed on the soil samples is presented in Table 2-5. Analyses are presented in Figures 2-8a through 2-8n (total arsenic only), and Section III of Appendix A (full HSL analyses).

TABLE 2-3
SOIL BORINGS SAMPLE ANALYSES

SOIL BORINGS	TOTAL NUMBER OF BORINGS	TOTAL NUMBER OF ANALYSES					
		TOTAL ARSENIC	E.P. TOX	INORGANICS	HSL POLLUTANTS		
					BNA	P/PCB	VOA
- On Grid	25	76	2	29	29	29	29
- Building #9	5	20	2	11	11	11	11
Total	30	96	4	40	40	40	40

2-19

7796b

6E60 100 NIA

TABLE 2-4
MONITORING WELL SUMMARY

CLUSTER IDENTIFICATION	WELL IDENTIFICATION	ACTUAL DEPTH	ACTUAL SCREEN INTERVAL	DRILLING METHOD	SOIL SAMPLES OBTAINED	PURPOSE
EW-1	EW-1-S	18'	3-8'	6" ID HSA	Two at screen setting	- Monitor contamination migrating under Blackwater Branch, eastern end of plume.
	EW-1-M	37'	27-37'	Mud Rotary	Two at screen setting	
	EW-1-D	105'	92-102'	Mud Rotary	Continuous SPT 0-6'; one every 10' from 15-105'	
EW-2	EW-2-S	18'	3-18'	6" ID HSA	Two at screen setting	- Monitor contamination migrating to Blackwater Branch, eastern end of plume.
	EW-2-M	37'	27-37'	Mud Rotary	Two at screen setting	
	EW-2-D	97'	87-97'	Mud Rotary	Continuous SPT 0-4'; one every 10' from 10-120'	
EW-4	EW-4-S	22'	6-21'	6" ID HSA	Two at screen setting	- Monitor contamination migrating NW from site at 3 depths.
	EW-4-M	45'	33-43'	Mud Rotary	One at screen setting	
	EW-4-D	110'	99-109'	Mud Rotary	Continuous SPT 0-10'; one every 10' from 10-110'	
EW-5	EW-5-S	20'	5-20'	6" ID HSA	Two at screen setting	- Monitor contamination migrating west from lagoon area at 3 depths.
	EW-5-M	49'	39-49'	Mud Rotary	Two at screen setting	
	EW-5-D	130'	116-126'	Mud Rotary	Continuous SPT 0-8'; one every 10' from 20-130'	
EW-6	EW-6-S	25'	7-22'	6" ID HSA	Two at screen setting	- Monitor contamination migration in lagoon area.
	EW-6-M	57'	47-57'	6" ID HSA	Continuous SPT 0-10'; one every 10' from 10-60'	
EW-7	EW-7-S	19'	4-19'	6" ID HSA	Two at screen setting	- Monitor contamination migrating north of site toward Blackwater Branch; determine vertical head profile by Branch.
	EW-7-M	63'	51-61'	Mud Rotary	One at screen setting	
	EW-7-D	111'	99-109'	Mud Rotary	Continuous SPT 0-4'; one every 10' from 10-110'	
EW-8	EW-8-S	24'	7-22'	6" ID HSA	Two at screen setting	- Monitor contamination at depth north of lagoon area.
	EW-8-M	70'	60-70'	6" ID HSA	Continuous SPT 0-12'; one every 10' from 20-70'	
EW-9	EW-9-S	25'	9-24'	6" ID HSA	Two at screen setting	- Monitor contamination moving northeast from site toward residences along Wheat Road.
	EW-9-M	75'	65-75'	Mud Rotary	Two at screen setting	
	EW-9-D	126'	114-124'	Mud Rotary	Continuous SPT 0-14'; one every 10' from 25-125'	
EW-10	EW-10-S	21'	4-19'	6" ID HSA	Two at screen setting	- Monitor contamination migrating west of site at 3 depths.
	EW-10-M	41'	30-40'	Mud Rotary	Two at screen setting	
	EW-10-D	106'	95-105'	Mud Rotary	Continuous SPT 0-8'; one every 10' from 15-105'	

TABLE 2-4 (Con't)

MONITORING WELL SUMMARY

<u>CLUSTER IDENTIFICATION</u>	<u>WELL IDENTIFICATION</u>	<u>ACTUAL DEPTH</u>	<u>ACTUAL SCREEN INTERVAL</u>	<u>DRILLING METHOD</u>	<u>SOIL SAMPLES OBTAINED</u>	<u>PURPOSE</u>
EW-11	EW-11-S	24'	9-24'	6" ID HSA	Two at screen setting Continuous SPT 0-10'; one every 10' from 10-60'	- Monitor contamination at depth in lagoon area.
	EW-11-M	66'	56-66'	6" ID HSA		
EW-12	EW-12-S	27'	9-24'	6" ID HSA	Two at screen setting Continuous SPT 0-6'; one every 10' from 15-65'	- Monitor contamination at depth migrating east of site toward residences.
	EW-12-M	70'	59-69'	6" ID HSA		
EW-13	EW-13-S	19'	4-19'	6" ID HSA	Two at screen setting Continuous SPT 0-6'; one every 10' from 10-50'	- Monitor contamination at depth migrating west of site; near former outdoor storage area.
	EW-13-M	51'	34-49'	Mud Rotary		
EW-14	EW-14-S	19'	3-18'	6" ID HSA	One at screen setting Continuous SPT 0-4'; one every 10' from 10-60'	- Monitor contamination at depth migrating south of site; in former outdoor storage area.
	EW-14-M	62'	45-55'	6" ID HSA		
EW-15	EW-15-S	25'	4.5-19.5'	6" ID HSA	Two at screen setting Two at screen setting Continuous SPT 0-6'; one every 10' from 15-105'	- Monitor contamination at depth migrating south-east of site; possible background well.
	EW-15-M	71'	56-69'	Mud Rotary		
	EW-15-D	117'	104-114'	Mud Rotary		

2-21

TABLE 2-5
WELL BORING SAMPLE ANALYSES

TOTAL NUMBER OF WELLS	TOTAL ARSENIC	TOTAL NUMBER OF ANALYSES						
		INORGANIC	HSL POLLUTANTS		VOA	GRAIN SIZE	ATTERBURG LIMITS	PERMEABILITY
			BNA	P/PCB				
36	186	37	37	37	37	31	4	4

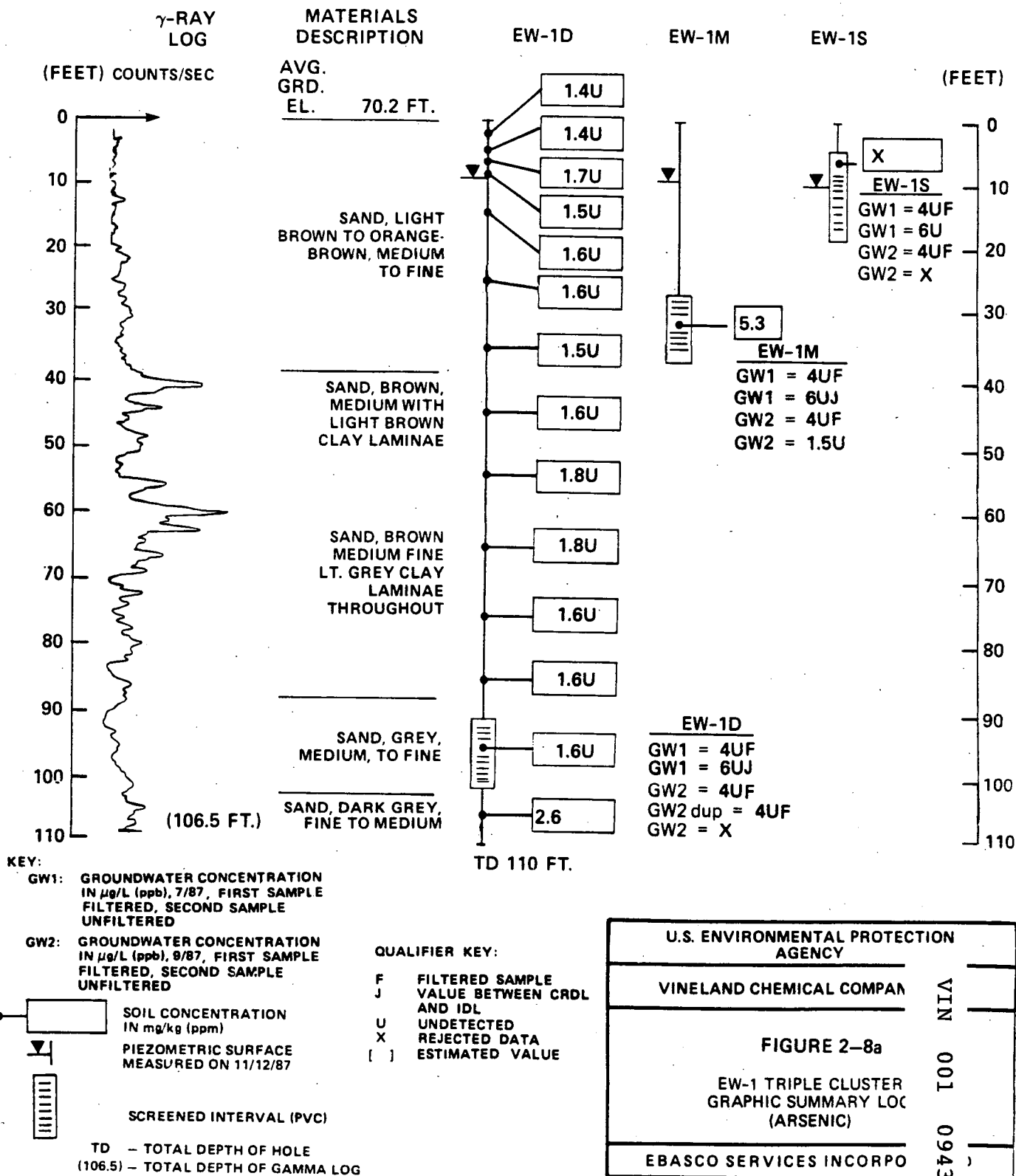
Note:

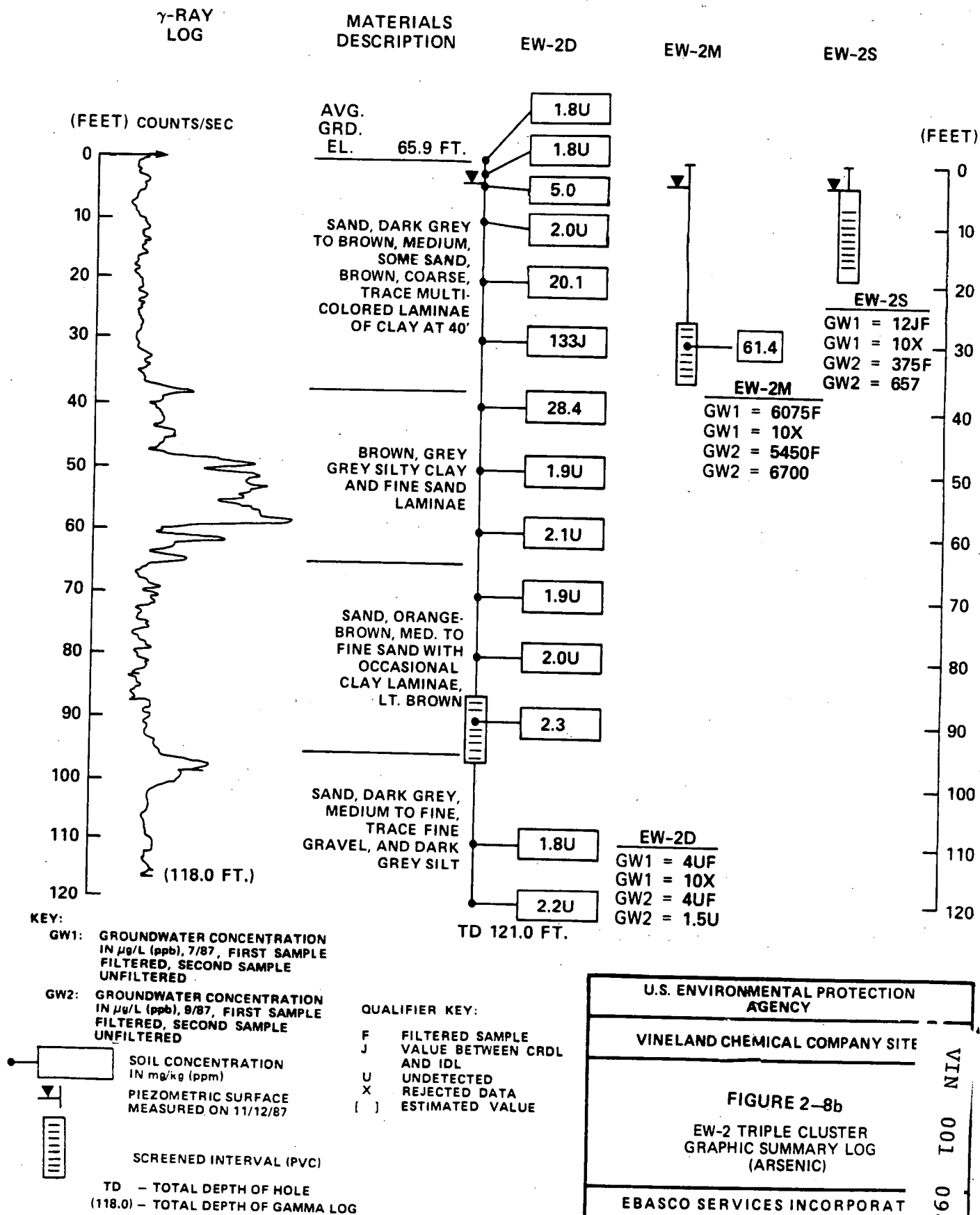
Total number of analyses includes duplicate analyses

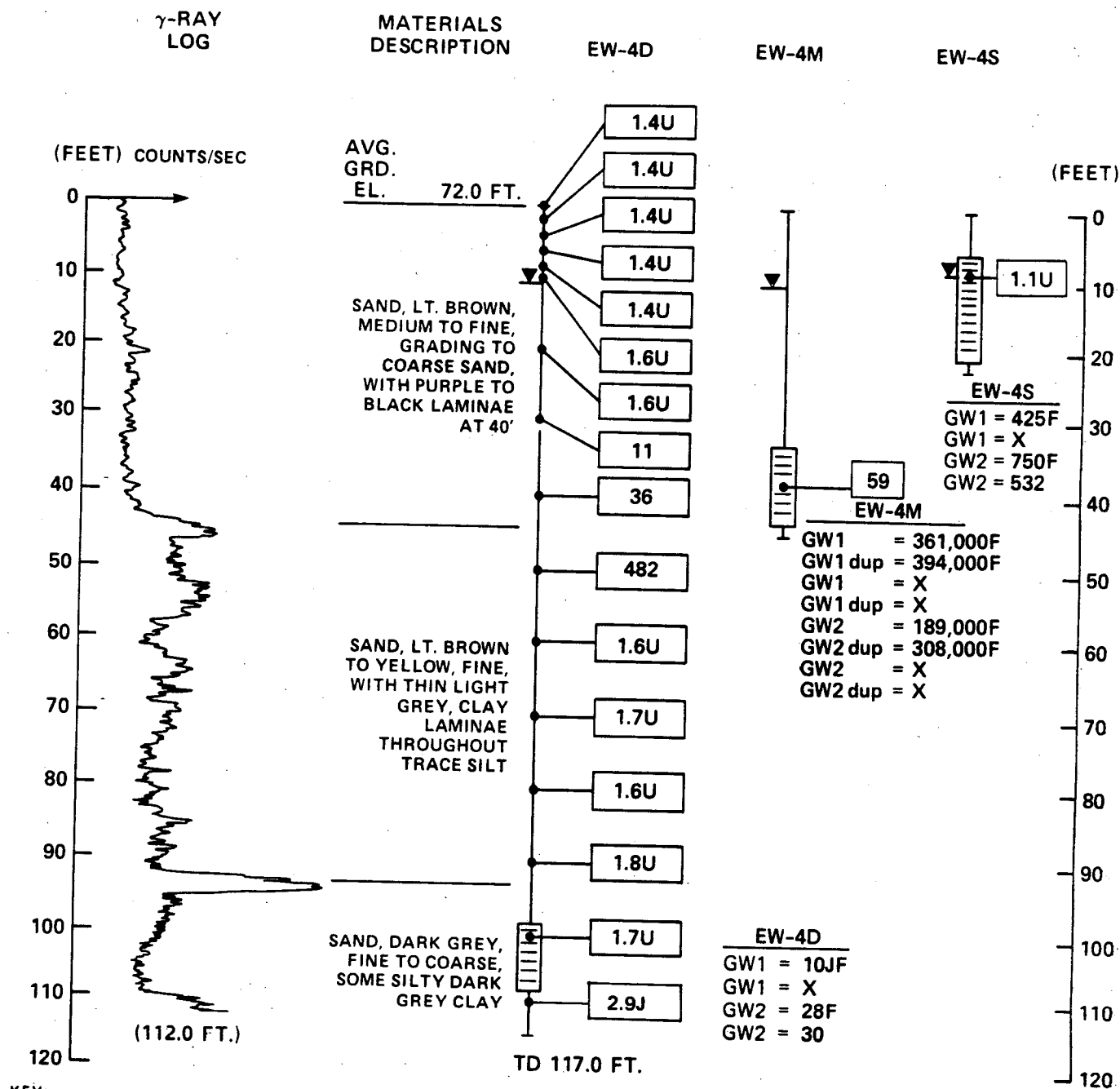
2-22

7769b

VIN 001 0942







KEY:

GW1: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 7/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

GW2: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 9/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

SOIL CONCENTRATION IN mg/kg (ppm)

PIEZOMETRIC SURFACE MEASURED ON 11/12/87

SCREENED INTERVAL (PVC)

TD - TOTAL DEPTH OF HOLE (112.0) - TOTAL DEPTH OF GAMMA LOG

QUALIFIER KEY:

F FILTERED SAMPLE VALUE BETWEEN CRDL AND IDL

J

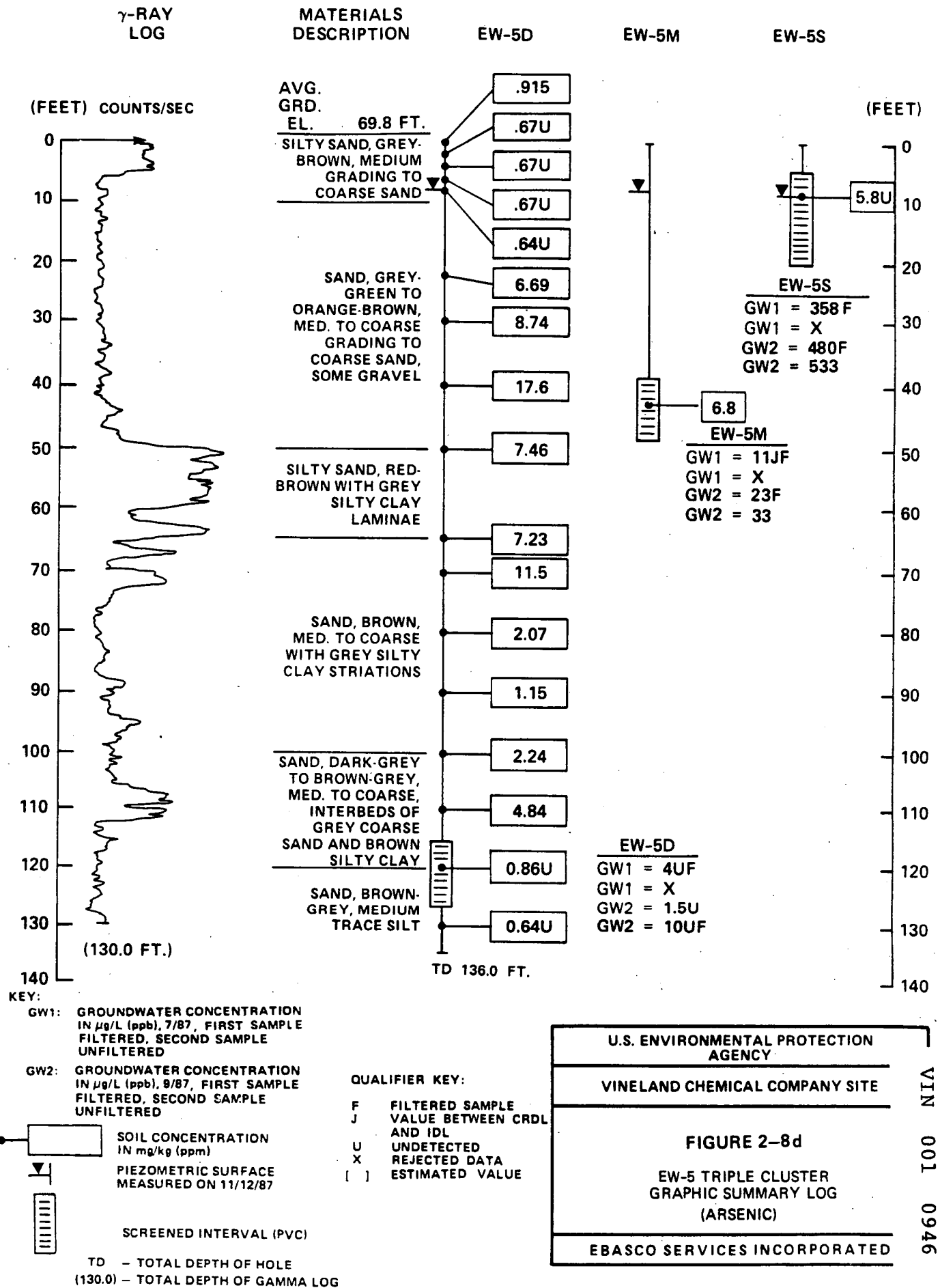
U UNDETECTED

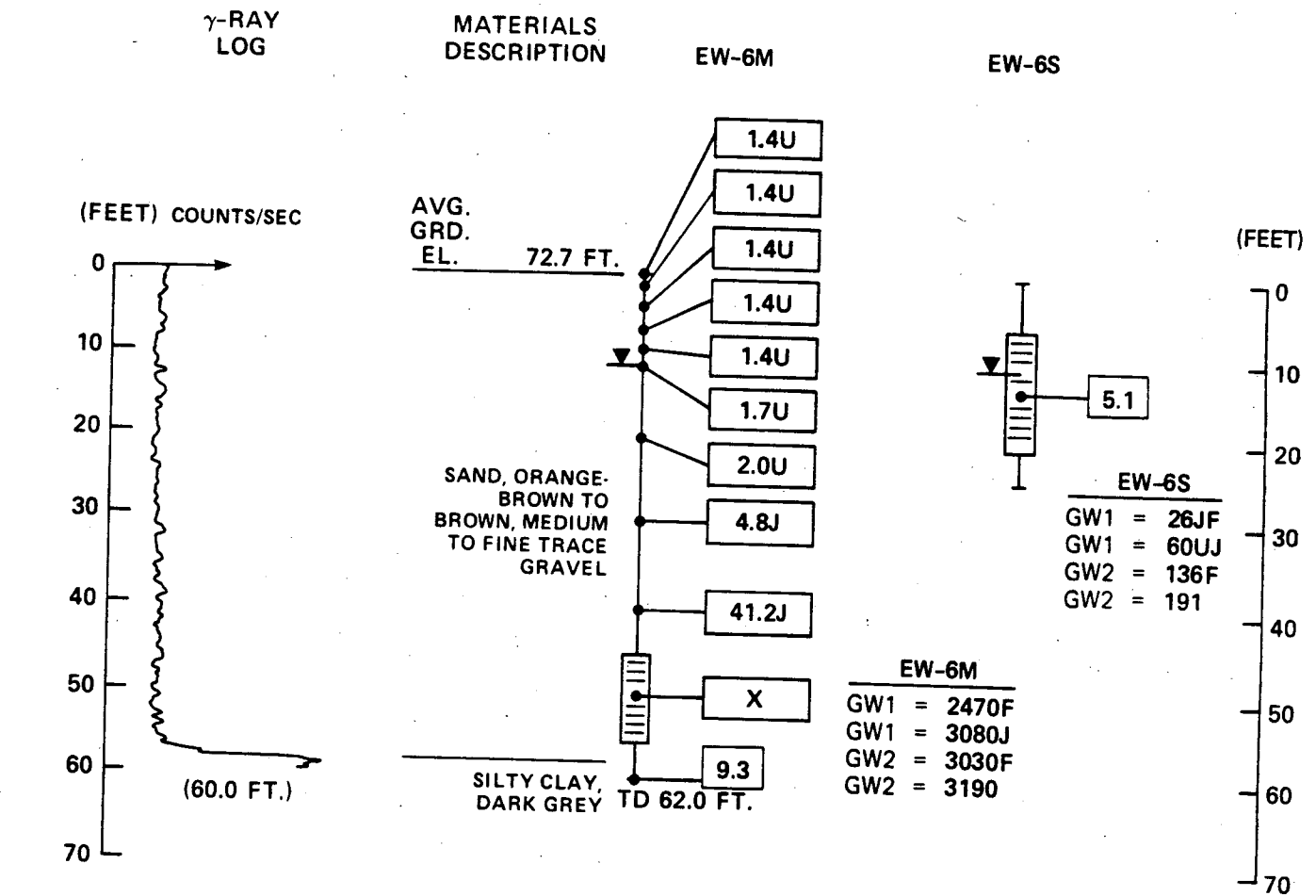
X REJECTED DATA

[] ESTIMATED VALUE

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SIT
FIGURE 2-8c
EW-4 TRIPLE CLUSTER GRAPHIC SUMMARY LOG (ARSENIC)
EBASCO SERVICES INCORPORATE

VIN 001 0945

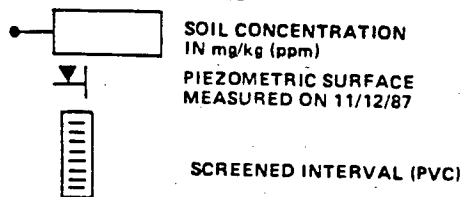




KEY:

GW1: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 7/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

GW2: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 9/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED



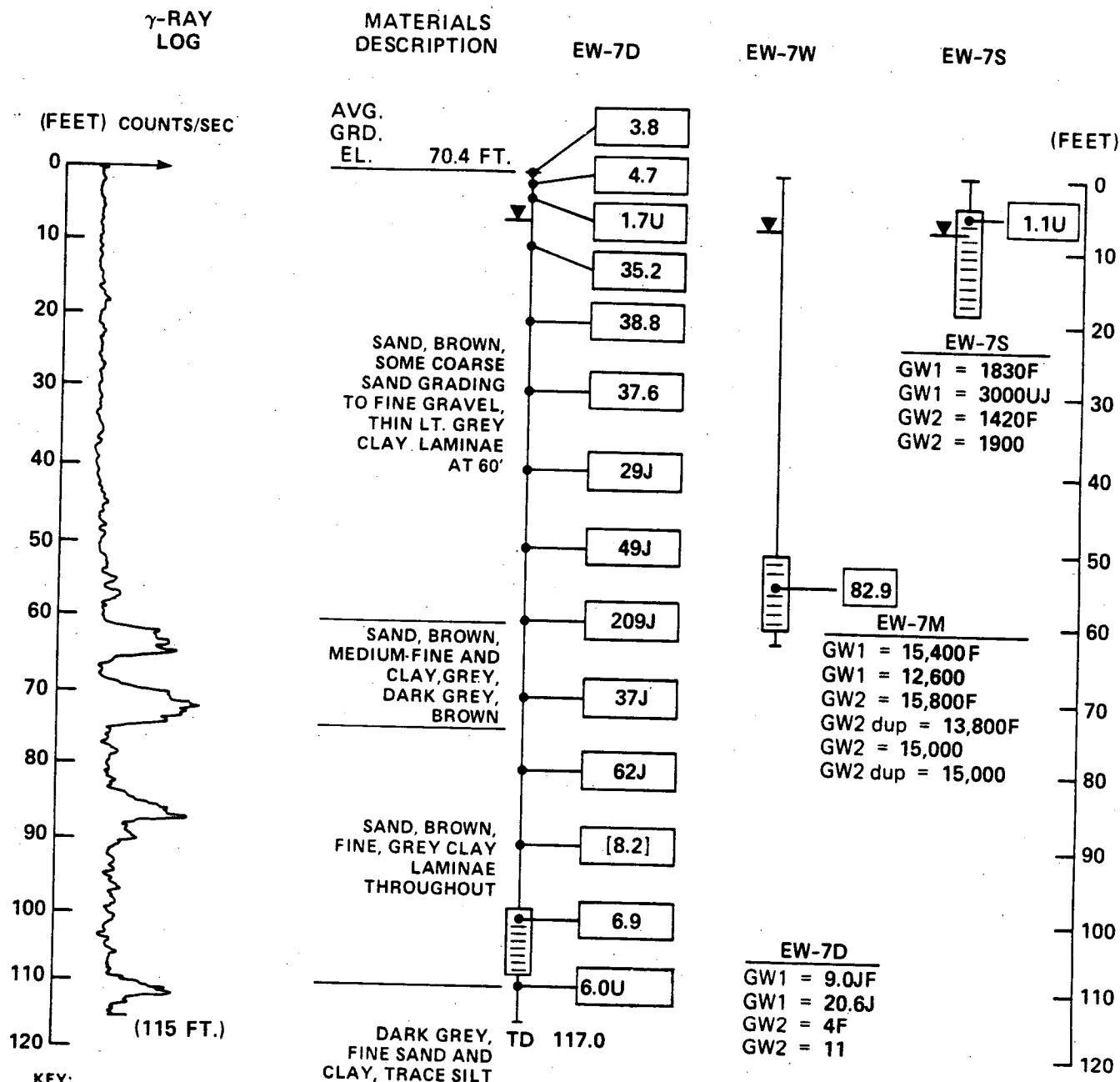
TD - TOTAL DEPTH OF HOLE
(60.0) - TOTAL DEPTH OF GAMMA LOG

QUALIFIER KEY:

F FILTERED SAMPLE
J VALUE BETWEEN CRDL AND IDL
U UNDETECTED
X REJECTED DATA
[] ESTIMATED VALUE

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 2-8e EW-6 DOUBLE CLUSTER GRAPHIC SUMMARY LOG (ARSENIC)
EBASCO SERVICES INCORPORATED

VIN 001 0947



KEY:

GW1: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 7/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

GW2: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 9/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

SOIL CONCENTRATION IN mg/kg (ppm)

PIEZOMETRIC SURFACE MEASURED ON 11/12/87

SCREENED INTERVAL (PVC)

TD - TOTAL DEPTH OF HOLE

(115) - TOTAL DEPTH OF GAMMA LOG

QUALIFIER KEY:

F FILTERED SAMPLE
J VALUE BETWEEN CRDL AND IDL
U UNDETECTED
X REJECTED DATA
[] ESTIMATED VALUE

U.S. ENVIRONMENTAL PROTECTION AGENCY

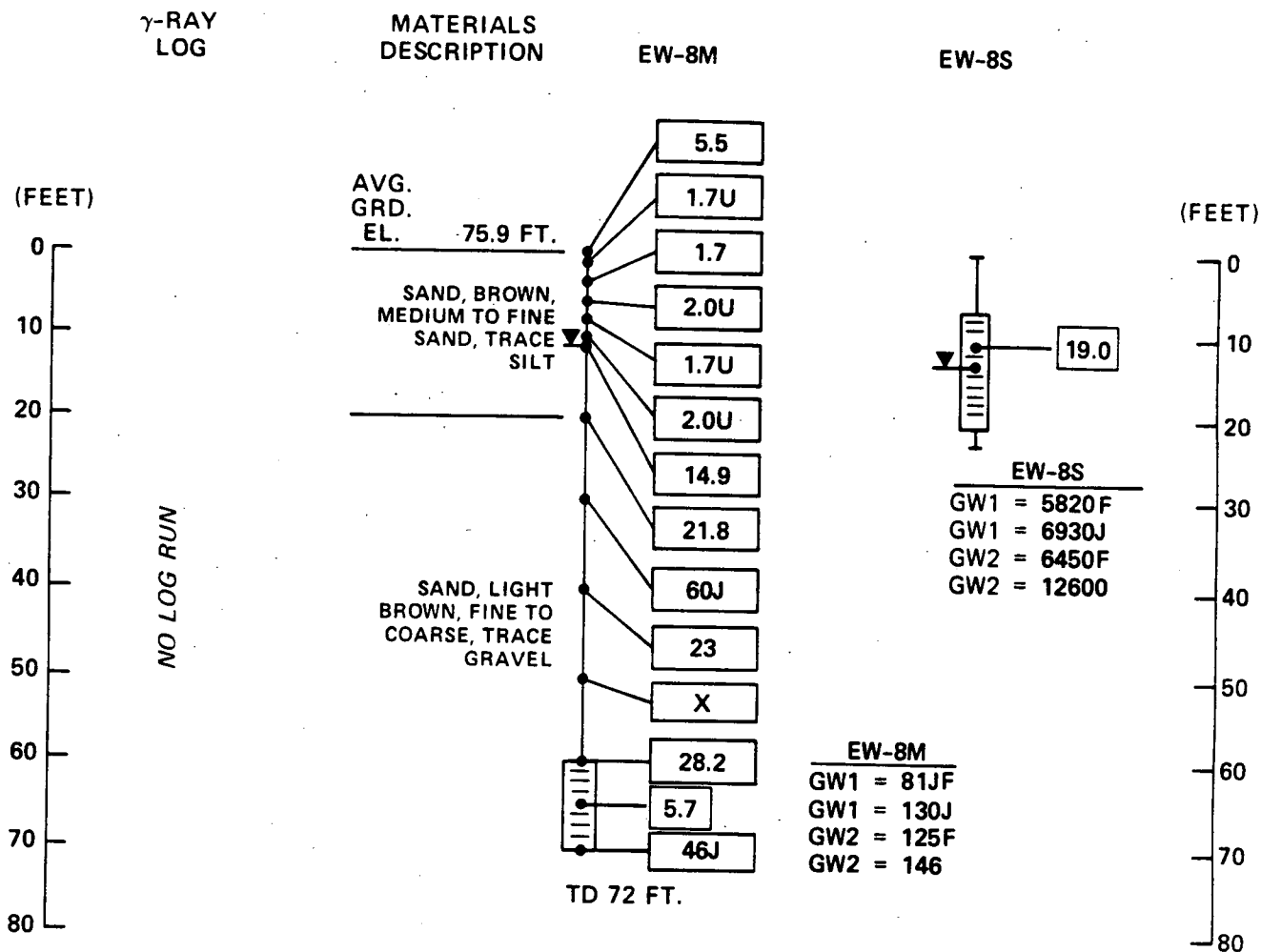
VINELAND CHEMICAL COMPANY SITE

FIGURE 2-8f

EW-7 TRIPLE CLUSTER GRAPHIC SUMMARY LOG (ARSENIC)

EBASCO SERVICES INCORPORATE

VIN 001 0948



KEY:

GW1: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 7/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

GW2: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 9/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

SOIL CONCENTRATION IN mg/kg (ppm)

PIEZOMETRIC SURFACE MEASURED ON 11/12/87

SCREENED INTERVAL (PVC)

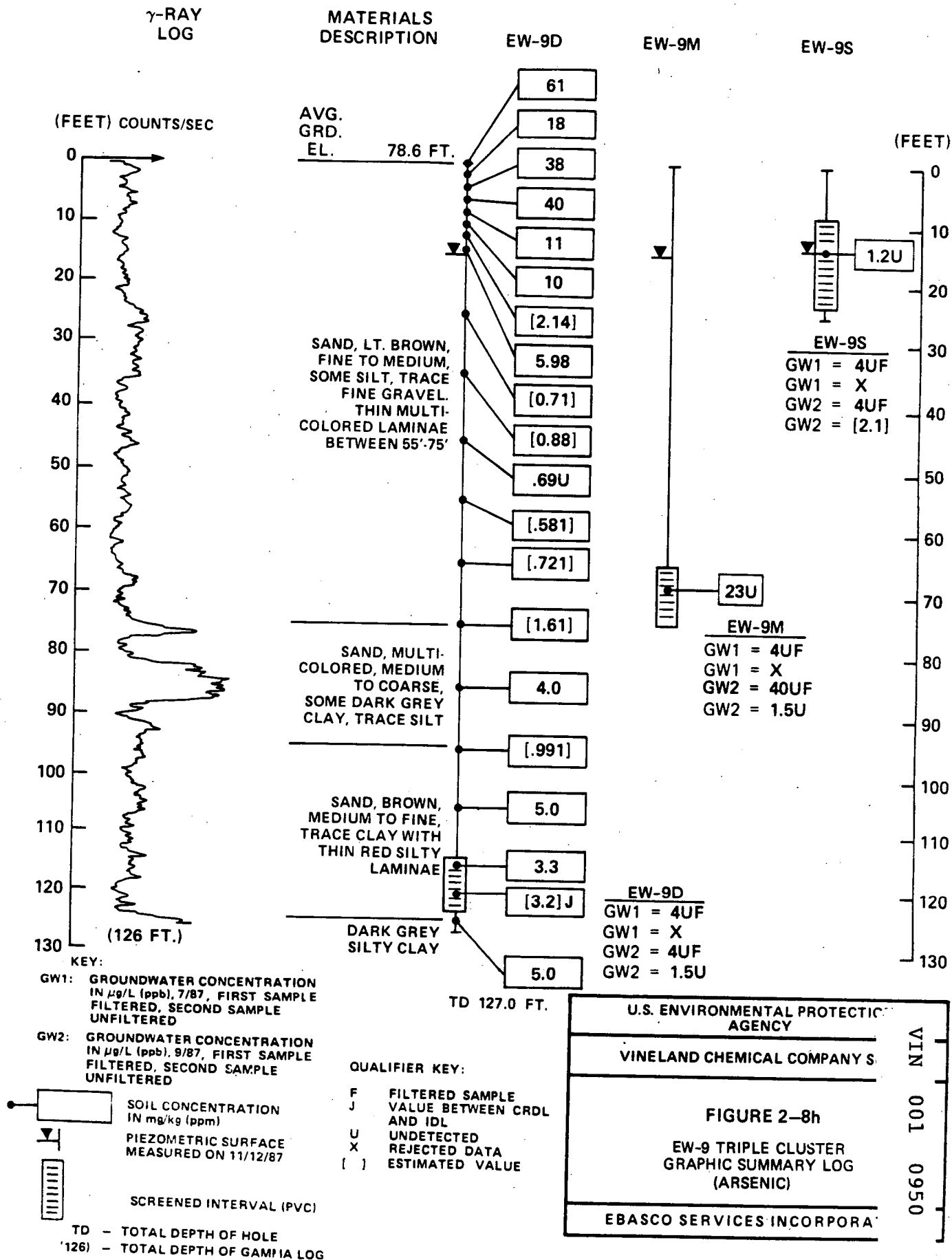
TD - TOTAL DEPTH OF HOLE

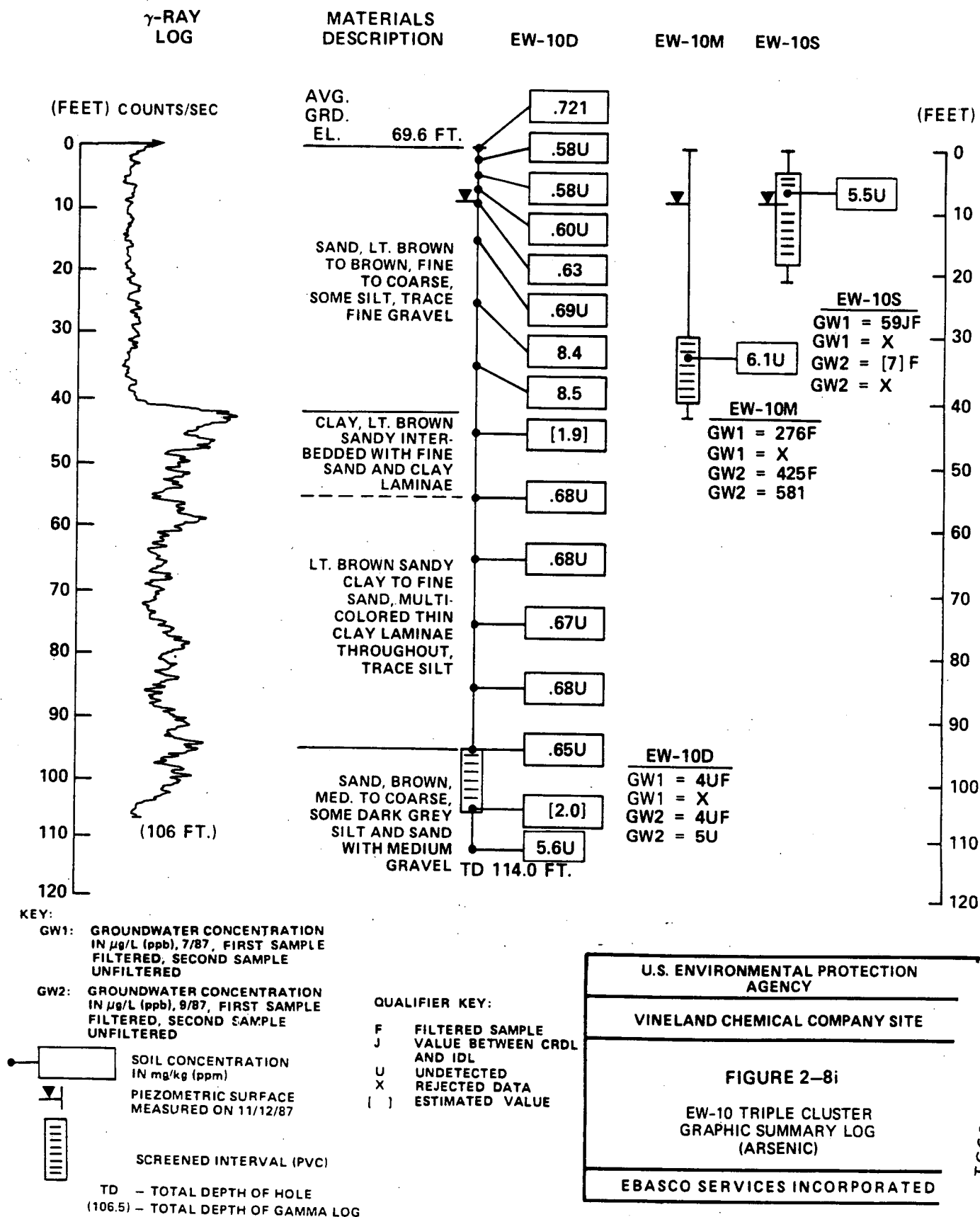
QUALIFIER KEY:

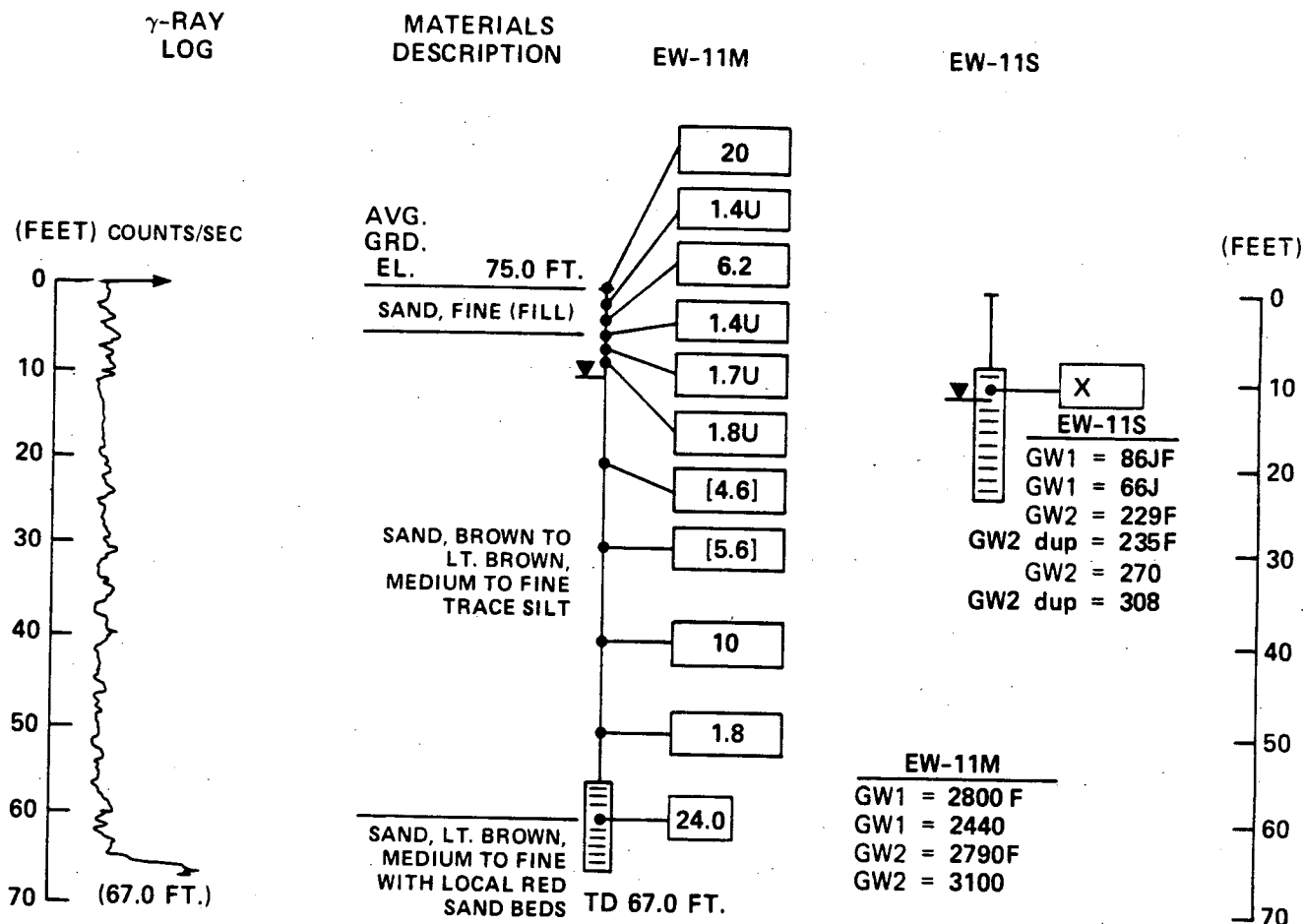
F FILTERED SAMPLE
J VALUE BETWEEN CRDL AND IDL
U UNDETECTED
X REJECTED DATA
() ESTIMATED VALUE

U.S. ENVIRONMENTAL PROTECTION AGENCY	
VINELAND CHEMICAL COMPANY SI	
FIGURE 2-8g	
EW-8 DOUBLE CLUSTER GRAPHIC SUMMARY LOG (ARSENIC)	
EBASCO SERVICES INCORPORAT	

VIN 001 0949







KEY:

GW1: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 7/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

GW2: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 9/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

SOIL CONCENTRATION IN mg/kg (ppm)

PIEZOMETRIC SURFACE MEASURED ON 11/12/87

SCREENED INTERVAL (PVC)

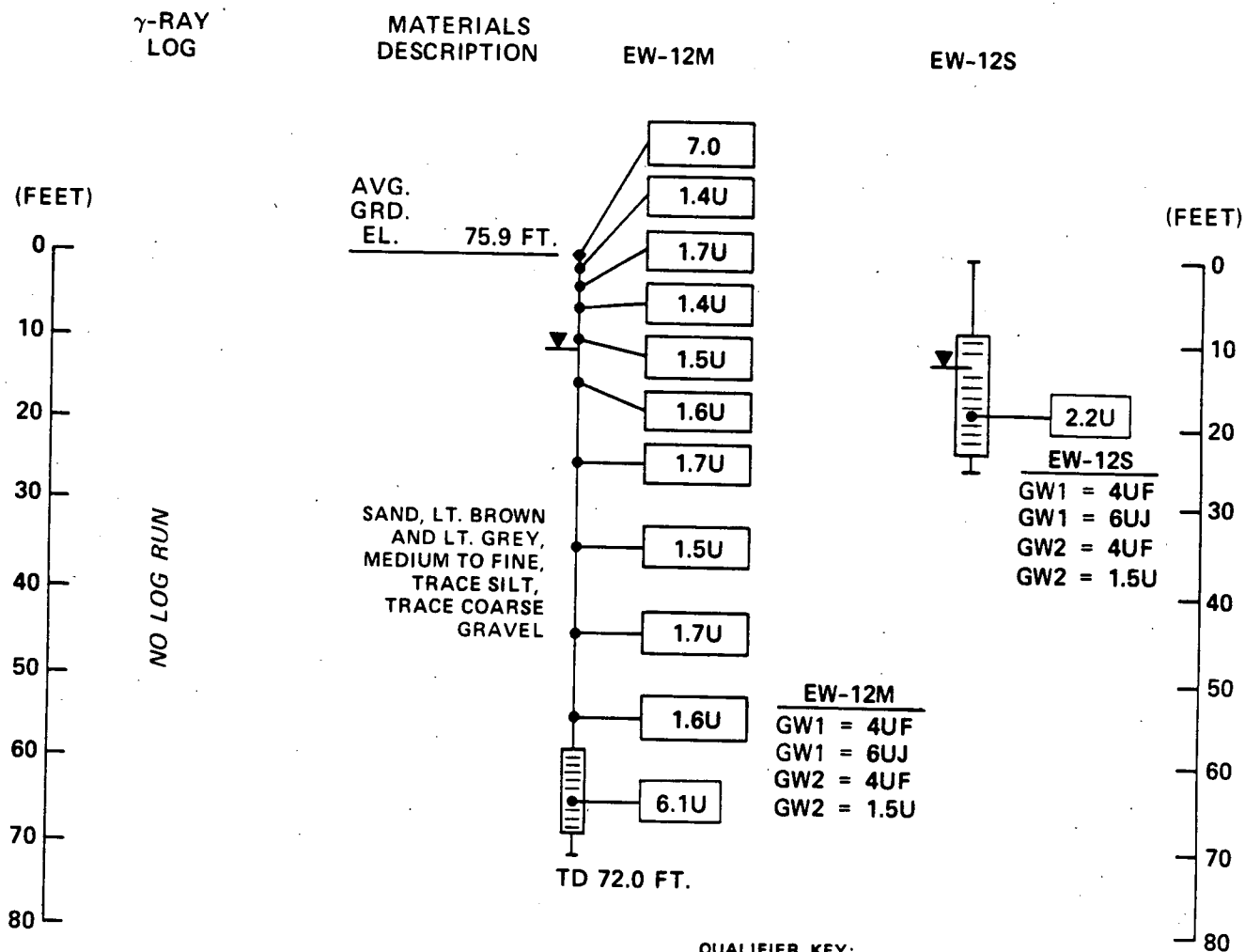
TD - TOTAL DEPTH OF HOLE (67.0) - TOTAL DEPTH OF GAMMA LOG

QUALIFIER KEY:

F FILTERED SAMPLE
J VALUE BETWEEN CRDL AND IDL
U UNDETECTED
X REJECTED DATA
[] ESTIMATED VALUE

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 2-8j
EW-11 DOUBLE CLUSTER GRAPHIC SUMMARY LOG (ARSENIC)
EBASCO SERVICES INCORPORATED

VIN 001 0952



KEY:

GW1: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 7/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

GW2: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 8/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

SOIL CONCENTRATION IN mg/kg (ppm)

PIEZOMETRIC SURFACE MEASURED ON 11/12/87

SCREENED INTERVAL (PVC)

TD - TOTAL DEPTH OF HOLE

QUALIFIER KEY:

F FILTERED SAMPLE

J VALUE BETWEEN CRDL AND IDL

U UNDETECTED

X REJECTED DATA

[] ESTIMATED VALUE

U.S. ENVIRONMENTAL PROTECTION AGENCY

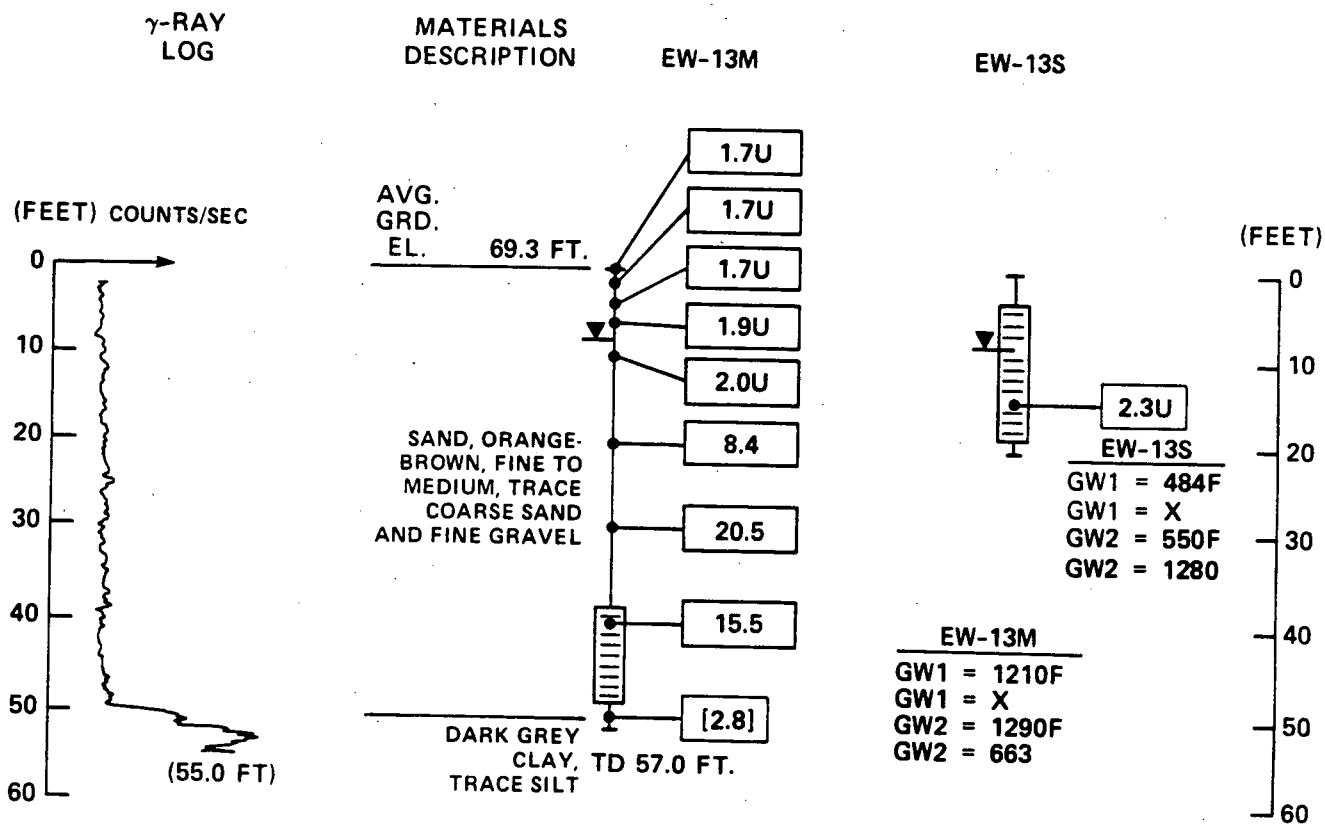
VINELAND CHEMICAL COMPANY SITE

FIGURE 2-8k

EW-12 DOUBLE CLUSTER GRAPHIC SUMMARY LOG (ARSENIC)

EBASCO SERVICES INCORPORATED

VIN 001 0953



KEY:

GW1: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 7/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

GW2: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 9/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

SOIL CONCENTRATION IN mg/kg (ppm)

PIEZOMETRIC SURFACE MEASURED ON 11/12/87

SCREENED INTERVAL (PVC)

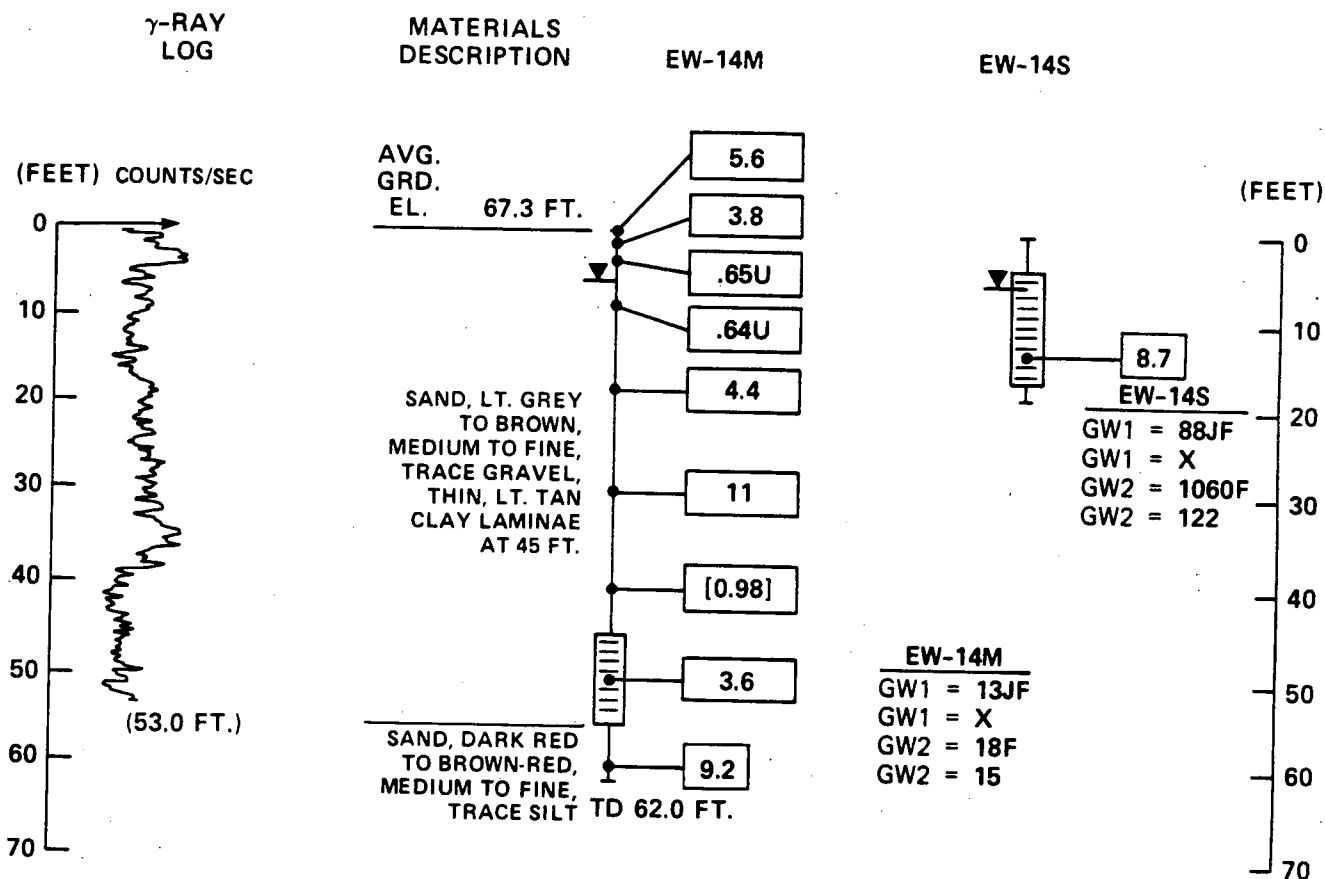
TD - TOTAL DEPTH OF HOLE
(55.0) - TOTAL DEPTH OF GAMMA LOG

QUALIFIER KEY:

F FILTERED SAMPLE
J VALUE BETWEEN CRDL AND IDL
U UNDETECTED
X REJECTED DATA
[] ESTIMATED VALUE

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SI
FIGURE 2-81
EW-13 DOUBLE CLUSTER GRAPHIC SUMMARY LOG (ARSENIC)
EBASCO SERVICES INCORPORATE

VIN 001 0954



KEY:

GW1: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 7/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

GW2: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 9/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

SOIL CONCENTRATION IN mg/kg (ppm)

PIEZOMETRIC SURFACE MEASURED ON 11/12/87

SCREENED INTERVAL (PVC)

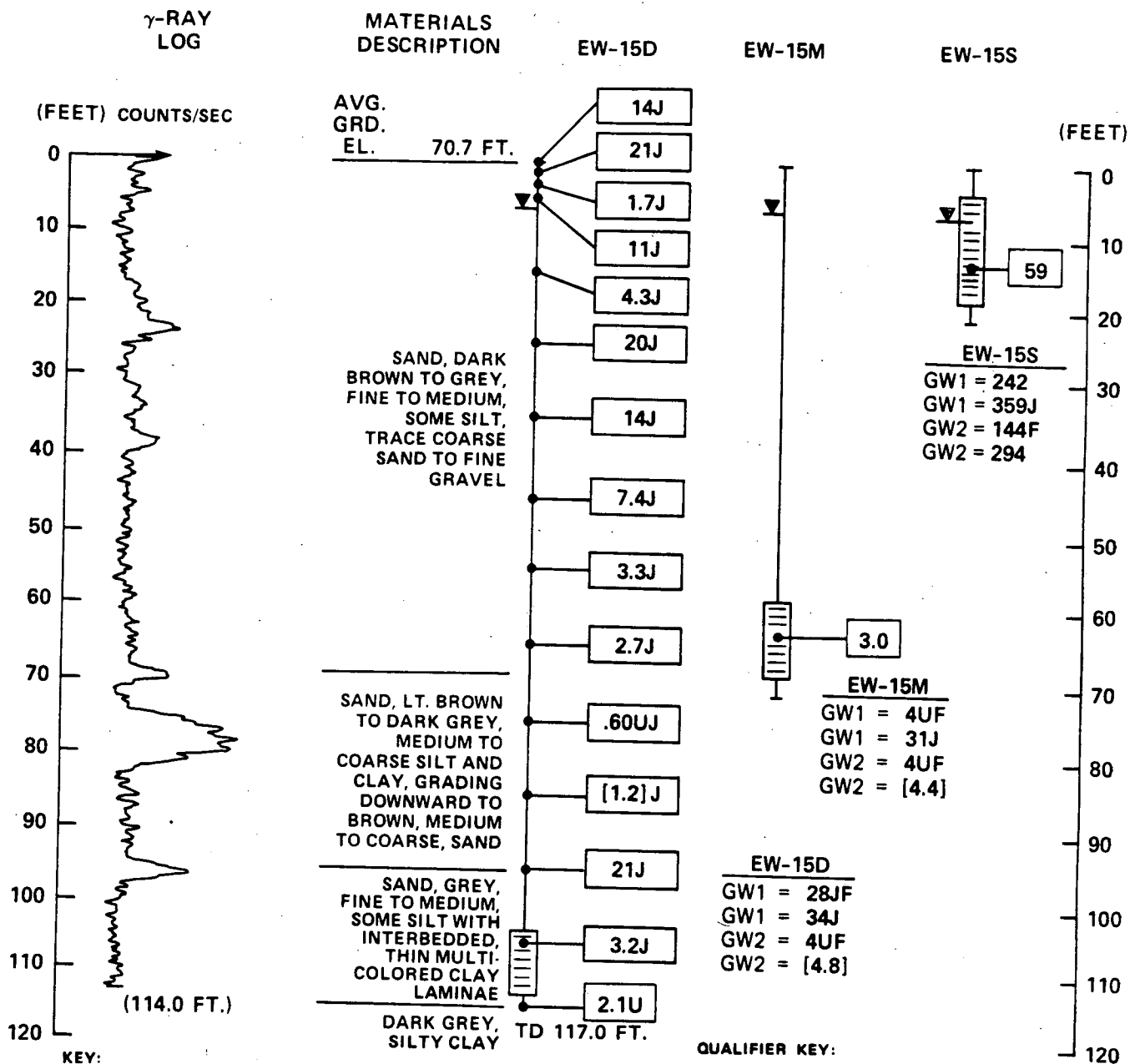
TD - TOTAL DEPTH OF HOLE (53.0) - TOTAL DEPTH OF GAMMA LOG

QUALIFIER KEY:

F FILTERED SAMPLE
J VALUE BETWEEN CRDL AND IDL
U UNDETECTED
X REJECTED DATA
[] ESTIMATED VALUE

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 2-8m
EW-14 DOUBLE CLUSTER GRAPHIC SUMMARY LOG (ARSENIC)
EBASCO SERVICES INCORPORATED

VIN 001 0955



KEY:

GW1: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 7/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

GW2: GROUNDWATER CONCENTRATION IN $\mu\text{g/L}$ (ppb), 9/87, FIRST SAMPLE FILTERED, SECOND SAMPLE UNFILTERED

SOIL CONCENTRATION IN mg/kg (ppm)

PIEZOMETRIC SURFACE MEASURED ON 11/12/87

SCREENED INTERVAL (PVC)

TD - TOTAL DEPTH OF HOLE
(114.0) - TOTAL DEPTH OF GAMMA LOG

QUALIFIER KEY:

F FILTERED SAMPLE
J VALUE BETWEEN CRDL AND IDL
U UNDETECTED
X REJECTED DATA
[] ESTIMATED VALUE

U.S. ENVIRONMENTAL PROTECTION AGENCY

VINELAND CHEMICAL COMPANY'S

FIGURE 2-8n

EW-15 TRIPLE CLUSTER GRAPHIC SUMMARY LOG (ARSENIC)

EBASCO SERVICES INCORPORATED

VIN 001 0956

2.4.3.2.2 Sample Methods

Soil samples were taken from the borings of the deepest well in each cluster, or from pilot holes which were drilled prior to installing the monitoring wells in a cluster. Samples were obtained continuously to the water table and at 5 foot intervals thereafter to the bottom of the deepest boring in a cluster. All of the samples to the water table, and every other sample below the water table, were analyzed for total arsenic. The remaining samples were used for visual geological identification.

Samples were also taken at the screen setting of each well, one sample for grain size analysis, and one sample for full HSL organics/inorganics analysis. Five exceptions to this are EW-4M, EW-7M, EW-9D, EW-14S, and EW-15D where grain size analyses were not taken because of insufficient sample recovery. Also, a full HSL sample was not taken from EW-2S, since at the top of the water table this well was screened in fill that was emplaced to provide a stable drilling base.

Shelby tube samples for geotechnical analyses were taken from four of the borings, EW-4D, EW-7D, EW-9D and EW-15D. The samples were taken from very fine grained materials seen at the bottom of these borings. By design, Shelby tube samples were to be taken from the bottom of all deep borings, but in EW-1D, EW-2D, EW-5D, and EW-10D the material at the bottom was non-cohesive sand and the material could not be retained within the Shelby tubes. The Shelby tube samples were analyzed for permeability and Atterberg Limits and were designed to distinguish the properties of the grey sandy clay and the sand formation above.

2.4.3.3 Building #9 Soil Borings

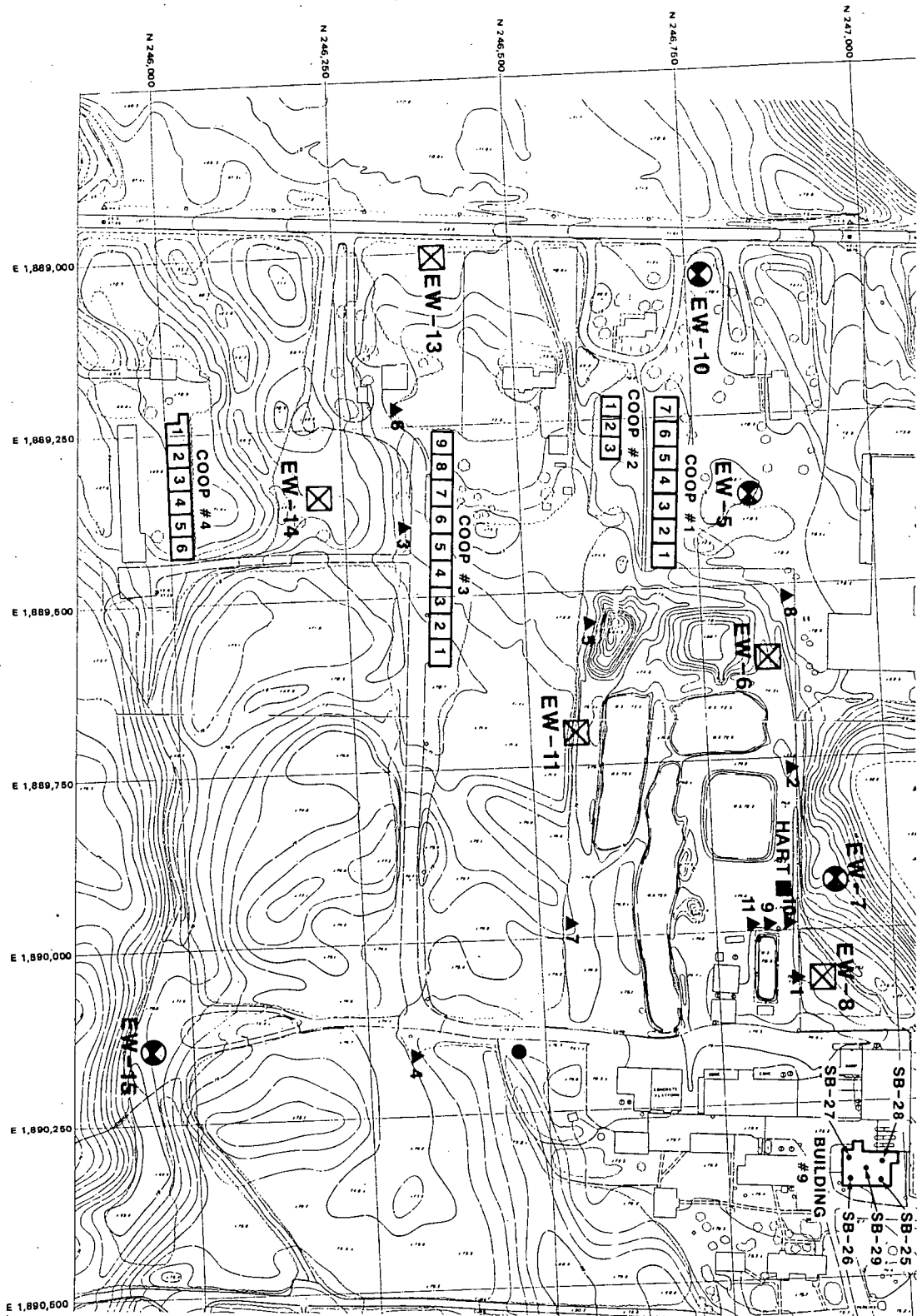
2.4.3.3.1 Sample Locations

On June 24 and June 25, 1987, five borings were conducted inside of Building #9 in the manufacturing area. Crystalline arsenic wastes reportedly existed beneath the floor of this building. The borings were placed such that one boring was placed in each corner of the building and one was placed in the center of the floor. Figure 2-7 shows the approximate location of borings SB-25, SB-26, SB-27, SB-28 and SB-29 within Building #9. The boring logs are presented in Appendix C, while the analyses performed were presented in Table 2-3. Analytical results are presented in Section IV of Appendix A.

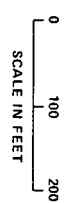
2.4.3.3.2 Sample Methods

Before the soil samples could be obtained, cores were cut out of the floor at the five boring locations. ViChem personnel washed down the floor before the coring began. A portable electric drill was used to drill a 3 inch diameter hole through the floor. Water was recirculated around the bit to keep it cool during the coring.

VIN 001 0958



- COOP #1-4
- BUILDING #9
- TRIPLE WELL CLUSTER (8)
- DOUBLE WELL CLUSTER (6)
- STREAM GAUGE STATIONS
- EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART (1)



TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1988.

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VINELAND CHEMICAL COMPANY SITE

FIGURE 2-7

BUILDING INVESTIGATION

EBASCO SERVICES INCORPORATED

VIN 001 0958

Two methods were used to collect the cooling water from the coring operation. First, a silicone sealant was placed around the hole and a barrel liner was sealed to the floor. The cooling water was to be containerized in the barrel liner. However, the sealant did not work, and a scan with an Organic Vapor Analyzer detected volatiles from the sealant. The first hole where this operation was tried was therefore plugged. Subsequent cores were drilled without using the barrel liner to containerize the cooling water.

The cores were pulled out from the hole and were set aside during the soil sampling. The cores showed that the floor consisted of one 2-inch layer of brick overlaying approximately 10 inches of concrete.

A 12-foot high tripod with a portable motorized cathead attached to it was set up to sample the soils. Drilling rods were attached to the cathead and two foot long carbon steel split spoons were attached to the bottom of the rods. The split spoons were lowered into the hole. The split spoons were advanced by hammering the rods with a 140-lb hammer. The hole was sampled continuously down to the water table. Augering was unnecessary because the holes created by the split spoons remained open for the next sampling interval.

Seventy-five percent of these samples were analyzed for total arsenic, while 25% were randomly selected for HSL organics/inorganics (+30) analyses. Two of the samples were analyzed for EP toxicity metals. SB-25 was sampled to 12 feet while SB-26, SB-27, SB-28 and SB-29 were sampled to 10 feet, according to the depth of the water table.

After all of the samples were obtained, the holes were backfilled with bentonite pellets and water. Grout slurry was placed on top of the pellets before the cores were placed in their proper holes. A sealant was placed over the five locations and the floor was cleaned of any water or debris.

2.5 MONITORING WELL INSTALLATION

2.5.1 Monitoring Well Locations

The Phase II monitoring well program was designed to delineate the contaminant plume and provide a data base for the FS. Figure 2-1 presented the actual Phase II monitoring well locations, while Table 2-4 summarized the actual depths and screened intervals. Monitoring well construction sheets are presented in Appendix D. The methods used to install the wells are standard methods and can be found in the approved FOP for the site.

Between May, 1987 and August, 1987 eight triple well clusters, consisting of three separate wells, and six double well clusters, consisting of two separate wells, were installed. The EW-3

double well cluster originally planned was not drilled because of problems with access into the swamp. The 36 wells vertically characterize the water table aquifer to its base at the grey silty marker bed, approximately 120 feet deep. The triple well clusters each consist of a deep well screened just above the grey layer, a shallow well screened from five feet above to ten feet below the water table, and an intermediate well screened between these two. The double well clusters consist of a shallow and intermediate well only.

The 36 monitoring wells and the existing ViChem wells were surveyed to the nearest 0.01 foot vertical and to the nearest 0.1 foot horizontal. Stream gauges were placed in the Blackwater Branch upstream and downstream of the site to monitor the Branch water level when rounds of water levels were taken. These stream gauges were surveyed in the same fashion as the monitoring wells.

2.5.2 Monitoring Well Construction

Before installing the monitoring wells in the three well clusters, a pilot hole was drilled. The pilot holes were drilled with 6x4 inch hollow stem augers. When running sands were encountered below the water table, a 3-inch mud rotary bit was used to advance the pilot hole to its design depth.

The monitoring well soil samples were obtained from the pilot holes. The pilot holes were logged with a gamma ray logger after reaching their design depths. The gamma ray logs provided continuous records of the geology to the bottom of the borings. These logs were useful in choosing the screen settings for the wells in the clusters. Figures 2-8a through 2-8n present the gamma ray logs for each well cluster.

In general, pilot holes were not drilled for the double well clusters. Instead, 11x6 inch hollow stem augers were advanced to the bottom of the boring for the intermediate well. The soil samples were collected from this boring, and a gamma ray log was run with the augers in place. The intermediate depth wells in the double well clusters were then installed inside these borings. The two exceptions to this were EW-6M and EW-11M, the two double well clusters in the lagoon area. A smaller 6 inch pilot hole was drilled first at each of these locations. Then these pilot holes were reamed with the larger 11x6 inch hollow stem augers to set the intermediate wells.

The design of the drilling program was to install a series of monitoring wells to fully characterize the aquifer to its base at a clay layer approximately 120 feet below the ground. The deep wells were to be installed on top of the clay layer. The shallow wells were to be screened from five feet above to ten feet below the water table. The intermediate wells were to be screened between these two at a depth of 60 to 70 feet. The aquifer was thought to be fairly uniform to the clay layer at approximately 120 feet.

The information found during the drilling program showed that this was not the case. The aquifer was not uniform to its base and the clay layer thought to be present at approximately 120 feet was in many places a fine sand. This geology is discussed in detail in Subsection 3.1.2. It is important to note here that the geology influenced the actual screen settings in the monitoring well clusters.

The deep wells were screened at the base of the middle sand on top of the lower sand that is discussed in Subsection 3.1.2. The bottom of these wells varied between approximately 100 and 120 feet across the site. The intermediate wells were all set at the base of the upper sand, on top of a unit with clay laminae called the banded zone. The shallow wells were all screened from five feet above to ten feet below the water table in the upper sand.

The drilling methods for the different types of wells varied. The deep wells were all installed using the mud rotary drilling method. Most intermediate wells were installed using hollow stem augers. Mud rotary was used on some of the intermediate wells that were in these well clusters. Hollow stem augers were used for all of the shallow wells.

Mud rotary drilling was the fastest method for installing the deep wells. For the first deep well that was installed, EW-15D, it was attempted to ream the pilot hole. However, this proved unsuccessful. For all remaining deep wells, a separate boring was drilled for the monitoring well and the pilot hole was abandoned by filling it with an approximate 1.5 lb/gallon bentonite/grout mixture (90% bentonite/10% grout).

The mud rotary bit was eight inches in diameter. Inorganic bentonite was used to make the drilling mud. The mud was recirculated in a mud tub brought to each borehole. A pit was dug next to each borehole and was used to collect solids which either settled out of the mud tub or which were separated from the mud using a sand separator. After completing the borings, excess drilling mud and solids were placed in the pit and stabilized by mixing in Portland cement. The stabilized mud pits were covered after they were solidified.

The deep monitoring wells were constructed of four inch diameter threaded flush joint Schedule 80 PVC. The screen slot size was 0.020 inch. No glue was used to seal the joints. Centralizers were used to center the screen and riser in the eight inch borehole. As mentioned, the depth of the screen setting was determined from the gamma ray log and the soil samples from the pilot hole.

After setting the screen to its desired depth, Morie #1 sand was added into the annulus between the borehole and the screen. The sand pack was brought up to approximately three feet above the

screen. Approximately three feet of inorganic bentonite pellets were then added to form a seal. The pellets were allowed to set up and the remainder of the annulus was grouted to the surface with an approximate 1.5 lb/gallon bentonite mud using a small amount of cement (90% bentonite/10% cement). A six inch surface casing was then grouted in over the PVC riser. Figure 2-9 presents the typical groundwater monitoring well construction diagram.

Most of the intermediate wells were installed using 11x6 inch hollow stem augers. For the intermediate wells that were the deepest well in a two well cluster, soil sampling was performed during drilling as described in Subsection 2.4.3.2. For the intermediate wells that were part of a triple well cluster, only one soil sample was collected at the screen setting. Some of these intermediate wells were installed using the mud rotary method.

The intermediate wells were constructed of Schedule 80 screen and riser. The construction details for these wells are the same as for the deep wells, except that centralizers were not used with the hollow stem augers. The sand pack, bentonite pellets, and bentonite grout were all added to the annulus between the PVC and the inside of the auger stem. The auger stems were pulled back continuously while adding the sand, pellets, and grout, ensuring that the well was centered in the borehole. Excess cuttings were placed in the pits.

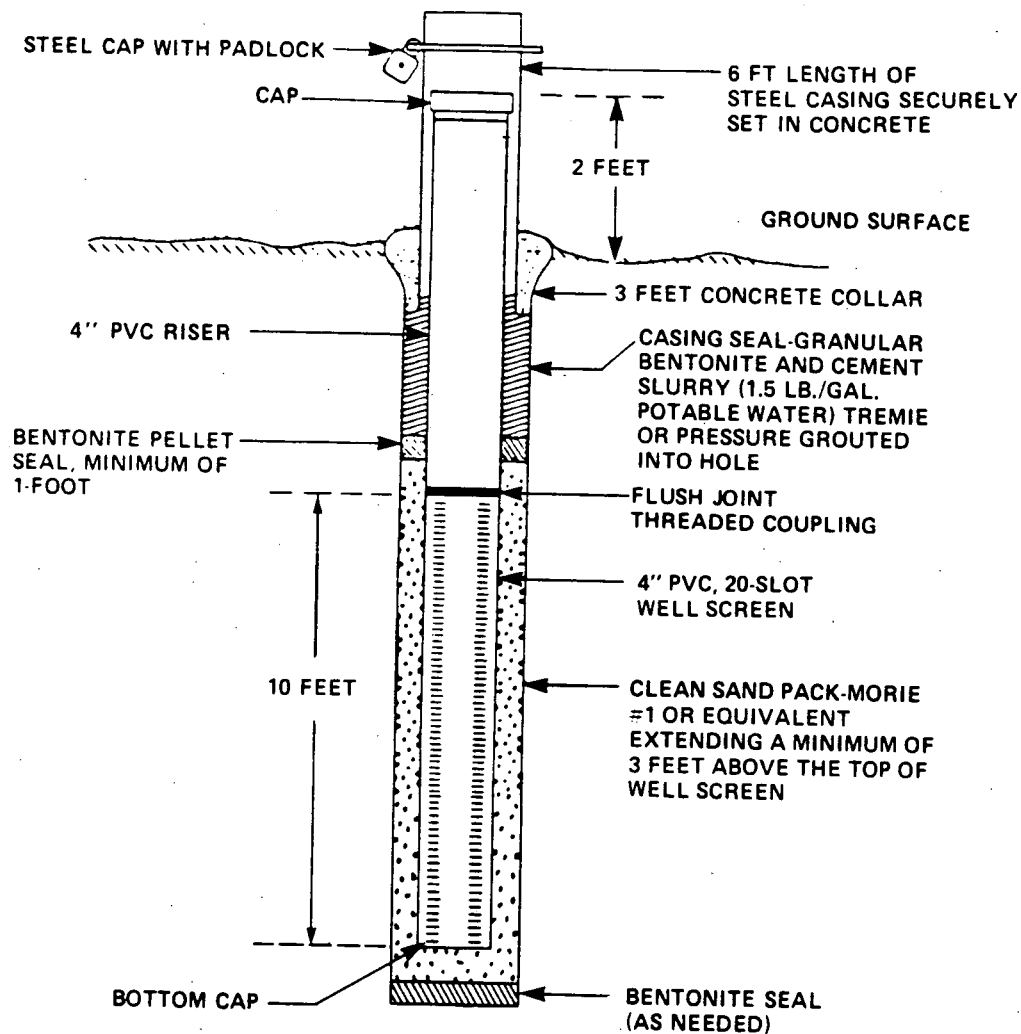
The shallow wells were all drilled with hollow stem augers. Only one soil sample was obtained from these wells, at the screen setting. These wells were screened from approximately ten feet below to five feet above the water table. In some cases, less than five feet of screen was installed above the water table if the water table was shallow. Pellets were again set on top of the sand pack, and grout added to the surface. Excess cuttings were placed in the mud pit.

Most of the wells were completed by grouting in a five foot long, six inch diameter outer casing at the surface over the PVC. However, the wells in the cluster along North Mill Road, EW-2D, -2M and -2S, were flush mounted to provide protection from traffic.

After all of the wells in a cluster were drilled, the pits for the cuttings were stabilized and graded. All cuttings were buried in the pits. No cuttings were containerized for later disposal.

Drilling water, bentonite mud, pure bentonite used to make the drilling mud, and the sand used in the sand pack were all sampled and analyzed for total arsenic. The samples obtained are presented in Table 2-6, with the results presented in Section III of Appendix A. In general, a sample of the mixed drilling mud was obtained whenever drilling mud was used in a boring.

TYPICAL GROUNDWATER MONITORING WELL



NOTE: DEEP AND INTERMEDIATE WELL SCREENS ARE 10 FEET LONG
SHALLOW WELL SCREENS ARE 15 FEET LONG, FROM 5 FEET ABOVE TO 10 FEET BELOW WATER TABLE.

NO SCALE

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AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 2-9

TYPICAL
GROUNDWATER MONITORING WELL

EBASCO SERVICES INCORPORATED

VIN 001 0963

TABLE 2-6

NUMBER OF DRILLING MUD, SAND, BENTONITE, AND
WATER SAMPLE ANALYSES

STATION NUMBER	DEPTH OF WELL	MEDIUM	TYPE OF SAMPLE	TOTAL ARSENIC
EW-1	Deep	Mud	Water	1
	Medium	Mud	Water	1
EW-2	Deep	Mud	Water	1
	Medium	Mud	Water	1
EW-4	Deep	Mud	Water	1
		Bentonite	Soil	1
		Sand	Soil	1
	Medium	Mud	Water	1
EW-5	Deep	Mud	Water	1
	Medium	Water	Water	1
		Mud	Water	1
EW-6	Medium	Mud	Water	1
EW-7	Deep	Mud	Water	1
	Medium	Mud	Water	1
EW-8	Medium	Mud	Water	1
EW-9	Deep	Mud	Water	3(a)
	Medium	Water	Water	1
		Mud	Water	1
EW-10	Deep	Mud	Water	1
	Medium	Mud	Water	1
EW-11	Medium	Mud	Water	1
EW-12	Medium	Mud	Water	1
EW-13	Medium	Mud	Water	1
EW-14	Medium	Mud	Water	1
EW-15	Deep	Mud	Water	1
		Mud	Water	1
		Water	Water	1
	Medium	Mud	Water	1
				<u>30</u>

Note:
(a) includes 1 duplicate sample

2.5.3 Monitoring Well Development

All wells installed during the Phase II investigation were developed by pumping and surging at least 24 hours after installation. The pump and surge method of development attempts to remove the fine material produced during drilling, creating a graded zone of sediment around the screen and stabilizing the formation so that the well will yield sand-free water. Two hours of development were allotted per well. One hour was devoted to continuous pumping while the second hour of development involved 10 minute pumping intervals intermixed with five minute non-pumping or surging intervals.

A suction pump and PVC tubing were used to pump water out of the well and into 55-gallon drums that were emptied into 5500 gallon storage tankers. Each well had its own length of PVC tubing to prevent cross-contamination.

The clarity of the water was tested by allowing water to flow into a glass jar. The wells that were drilled with mud took more than two hours to become clear. The shallow wells and the wells that were drilled with no drilling fluid became clear in less than two hours. On average, each well was developed for two hours.

2.6 GROUNDWATER INVESTIGATION

2.6.1 Sample Locations

Two rounds of groundwater samples were taken from the 36 Ebasco installed monitoring wells and the 11 ViChem monitoring wells. In addition, one sample was obtained from the deep monitoring well installed by ViChem in the lagoon area (labeled "HART Well"), and one sample was obtained from the ViChem production well. The location of all of these wells was presented in Figure 2-1. Section V in Appendix A presents the analytical results for these wells, while Tables 2-7 and 2-8 present summaries of the analyses performed in each groundwater sampling event. The methods used to obtain the samples are standard methods and can be found in the approved FOP for the site.

The groundwater samples were taken from July 20 to July 28, 1987 and from September 15 through September 29, 1987. At least two weeks transpired between monitoring well installation and sampling.

2.6.2 Sample Methods

All of the monitoring wells and the Hart well were purged prior to sampling. The ViChem production well runs continuously; therefore, there was no need to purge this well. The sample was obtained from a bleed valve at the well head.

TABLE 2-7

EBASCO WELL GROUNDWATER SAMPLING ANALYSES
SAMPLING EVENT #1 (7/87)

TOTAL NUMBER OF WELLS	TOTAL NUMBER OF ANALYSES				DISSOLVED ARSENIC
	INORGANIC	BNA	VOA	P/PCB	
48	50	13	50	50	50

Note:

Total number of analyses includes duplicate analyses.

TABLE 2-8

EBASCO WELL GROUNDWATER SAMPLING ANALYSES
SAMPLING EVENT #2 (9/87)

TOTAL NUMBER OF WELLS	TOTAL NUMBER OF ANALYSES				
	INORGANIC	BNA	VOA	P/PCB	DISSOLVED ARSENIC
48	54	15	54	54	54

Note:

Total number of analyses includes duplicate analyses.

The wells were purged with a suction pump and a downhole suction line made of ASTM D-2239 PVC tubing. A check valve was attached to the end of the suction line to prevent backflush. The purge water was containerized at the well head into 55 gallon drums. The water was then transported and pumped into the tankers stored on-site. At the end of the program, the tanker contents were disposed off-site.

Three to five well volumes were purged from each well. The pH, specific conductance, and temperature of the purge water was measured initially, after each well volume, and at the end of purging. The volume of water purged from each well depended on how quickly the water became clear and how quickly the water quality measurements stabilized with purging. Table 2-8A lists the actual well volumes purged from each well in each sampling round and the elapsed time between the end of purging and the time of sampling. These measurements were recorded on the Well Purge Data Sheet shown in Figure 2-10. The water quality measurements are discussed in Section 4.0 and are summarized in Table 4-6a.

After purging, the suction line was removed and the well's water levels returned to static. This water level recovery through time was recorded for each well to determine the physical characteristics of the aquifer. As discussed in Subsection 3.4.1, the water level recovery data yielded poor values of aquifer transmissivity, probably as a result of well inefficiency.

The wells were sampled generally within three hours after water levels recovered. Samples were obtained using stainless steel bailers suspended on teflon coated stainless steel wire. The bailers and the wire were decontaminated between each use.

All of the groundwater samples were analyzed for dissolved arsenic, HSL VOA (+10), HSL inorganics (unfiltered), and pesticides/PCBs. In addition, 25% of the groundwater samples were analyzed for acid/base/neutral extractables. The dissolved arsenic aliquot was filtered in the field. The dissolved arsenic and the unfiltered HSL inorganics aliquots were preserved prior to shipment with nitric acid to a pH of less than 2. All of the samples were iced prior to shipment.

2.6.3 Aquifer Testing

Several physical tests were performed on the aquifer. As mentioned, water level recovery was measured in each well after purging to attempt to obtain single-well pumping test data. This effort yielded inaccurate values of transmissivity. A pumping test was performed using ViChem's well MW-10 as the pumping well and measuring the drawdown in ViChem wells MW-11 and MW-9. Fifteen complete rounds of water level measurements were taken. These measurements are summarized in Table 3-3. Finally, water level recorders were installed on clusters EW-15, EW-5, EW-4, and EW-7 to obtain continuous recordings of water levels through time. The aquifer testing is discussed in Section 3.4, Hydrogeologic Investigation.

TABLE 2-8A

GROUNDWATER SAMPLING WELL PURGE DATA

<u>WELL</u>	<u>ROUND 1</u> <u>(Well</u> <u>Volumes)</u>	<u>ELAPSED TIME</u> <u>BETWEEN END</u> <u>OF PURGING</u> <u>AND SAMPLING</u> <u>(minutes)</u>	<u>ROUND 2</u> <u>(Well</u> <u>Volumes)</u>	<u>ELAPSED TIME</u> <u>BETWEEN END</u> <u>OF PURGING</u> <u>AND SAMPLING</u> <u>(minutes)</u>
EW-1S	7	21	8	9
EW-1M	6	43	6	11
EW-1D	4	58	4	22
EW-2S	7	50	7	47
EW-2M	3	7	5	53
EW-2D	3	0	3	60
EW-4S	5	97	5	67
EW-4M	5	93	5	50
EW-4D	5	129	4	67
EW-5S	6	98	6	46
EW-5M	4	93	4	50
EW-5D	4	234	3	9
EW-6S	5	29	6	11
EW-6M	4	20	4	7
EW-7S	7	18	7	14
EW-7M	4	14	3	12
EW-7D	5	15	4	7
EW-8S	4	10	10	11
EW-8M	3	8	4	9
EW-9S	5	83	8	11
EW-9M	3	51	3	27
EW-9D	3	7	4	14
EW-10S	7	69	7	43
EW-10M	6	82	6	44
EW-10D	4	137	5	84
EW-11S	5	10	7	3
EW-11M	4	5	3	12
EW-12S	6	10	7	9
EW-12M	3	1	3	51
EW-13S	8	29	7	14
EW-13M	4	29	3	24
EW-14S	7	157	7	7
EW-14M	10	106	3	8
EW-15S	5	4	5	27
EW-15M	3	18	4	7
EW-15D	5	4	3	8
MW-1	8	0	7	27
MW-2	8	6	7	9
MW-3	4	37	4	9
MW-4	5	34	5	8
MW-5	4	32	4	8
MW-6	4	42	4	10
MW-7	4	0	3	19
MW-8	5	301	5	1
MW-9	3	2	3	2
MW-11	5		5	9

FIGURE 2-10

VINELAND CHEMICAL COMPANY SITE
WELL PURGE DATA SHEET

Well I.D. _____
Ø

Date _____

Well Depth (from TOC) = _____ ft

Well Diameter (d) = _____ in

Static Water Level (from TOC) = _____ ft

Well Radius $\left(\frac{d}{2}\right)$ = _____ in

Height of Water in Well

T = Depth (ft) - Static Water Level (ft)

T = _____ - _____

T = _____ ft

Gallons of Water per Well Volume

Volume = $0.163 \times T(\text{ft}) \times r(\text{in})^2$

= $0.163 \times \text{_____} \times \text{_____}^2$

= _____ gallons

Total Volume Purged

Design = _____ gallons

Actual = _____ gallons

Water Quality

	PH (SU)	SP COND (μ mhos/cm)	TEMP (°C)
Initial	_____	_____	_____
Volume 1	_____	_____	_____
Volume 2	_____	_____	_____
Volume 3	_____	_____	_____
Volume 4	_____	_____	_____
Volume 5	_____	_____	_____

Purge Method

_____ SUCTION PUMP _____ SUBMERSIBLE PUMP _____ BAILER _____ OTHER _____

Notes/Observations: _____

Ebasco Sampler(s) _____

VIN 001 0970

2.7 CHICKEN COOP INVESTIGATION

2.7.1 Sample Locations

On July 9, 1987 one composite dust sample was obtained from each of the four chicken coops on-site. Figure 2-7 showed the locations of the coops and the rooms inside. The analyses performed on the samples are shown in Table 2-9. The analytical results of the dust samples are presented in Section VI of Appendix A, while the analyses are summarized in Table 4-7.

These coops reportedly had been used to store wastes and/or products in the past. Each of the four coops had a different number of rooms in it; therefore each coop had sampling points that were randomly distributed throughout the entire structure. The dust on the walls and floors was sampled and an inventory of the contents of each coop was taken.

Coop #1, the northern-most coop, has seven rooms. One of the rooms is being used for ordinary domestic storage while the rest of the coop is relatively empty. Rooms #1 and #2 are dirty and Rooms #3 through #6 are clean. The samples were taken off of the concrete floor and window sills in each room. Some of the windows were boarded up.

Coop #2 has three rooms with the eastern-most room being used for domestic storage. The windows in Coop #2 were blown out. The floor consisted of unpaved dirt. The samples were also taken off of the floor and window sills in each room.

Coop #3 has nine rooms. This coop is being actively used by ViChem for storage, and the doors are locked. The coop was boarded up entirely with the ninth room being inaccessible throughout the sampling. Room #1 stores pump parts and lab equipment, Room #2 appeared to contain a track on which items could have been transported from one room to another. There were about 180 drums in this room with signs on them that read diobromomethane, sodium bromide and sodium thiocyanate. Room #3 contained about 200 plastic, steel and cardboard drums that were packed very tightly. Room #4 appeared to be rebuilt. Dust masks, Tyvek and about 35 drums were present. Five of the drums were made of deteriorated cardboard. Stickers on these drums indicate that they contained borax, lime, soda and diatomaceous earth. Room #5 contained approximately 180 plastic & steel drums with sodium bromide and sodiumthiocyanate. Room #6 contained boxes of insulation and forms of asbestos on pipe insulation. Room #7 and Room #8 contained steel and plastic drums in poor condition. This coop has a concrete floor.

Coop #4 had six rooms; the western-most room was used for housing chickens, Room #2 was being used for domestic storage and the rest of the rooms were empty. There were rust stains on

TABLE 2-9
NUMBER OF COOP DUST SAMPLE ANALYSES

<u>STATION NUMBER</u>	<u>HSL INORGANIC</u>
Coop #1	1
Coop #2	1
Coop #3	2*
Coop #4	1

*Includes 1 Duplicate

the floor of Rooms #1 and #3 indicating the previous presence of drums in this coop. This sound structure has all of its windows open and had a concrete floor.

2.7.2 Sample Methods

One combined dust sample was obtained from each of the four chicken coops. The samples were obtained with small hand held vacuum cleaners. One vacuum cleaner was used to collect the dust sample from each coop. The dust samples were obtained from the floor, window sills, or other locations where dust accumulated. The dust was emptied into eight ounce jars before being sent to a CLP laboratory.

All of the dust samples were analyzed for HSL inorganics. One duplicate sample from Coop #3, the actively used structure, was also obtained.

2.8 LAGOON INVESTIGATION

2.8.1 Sample Locations

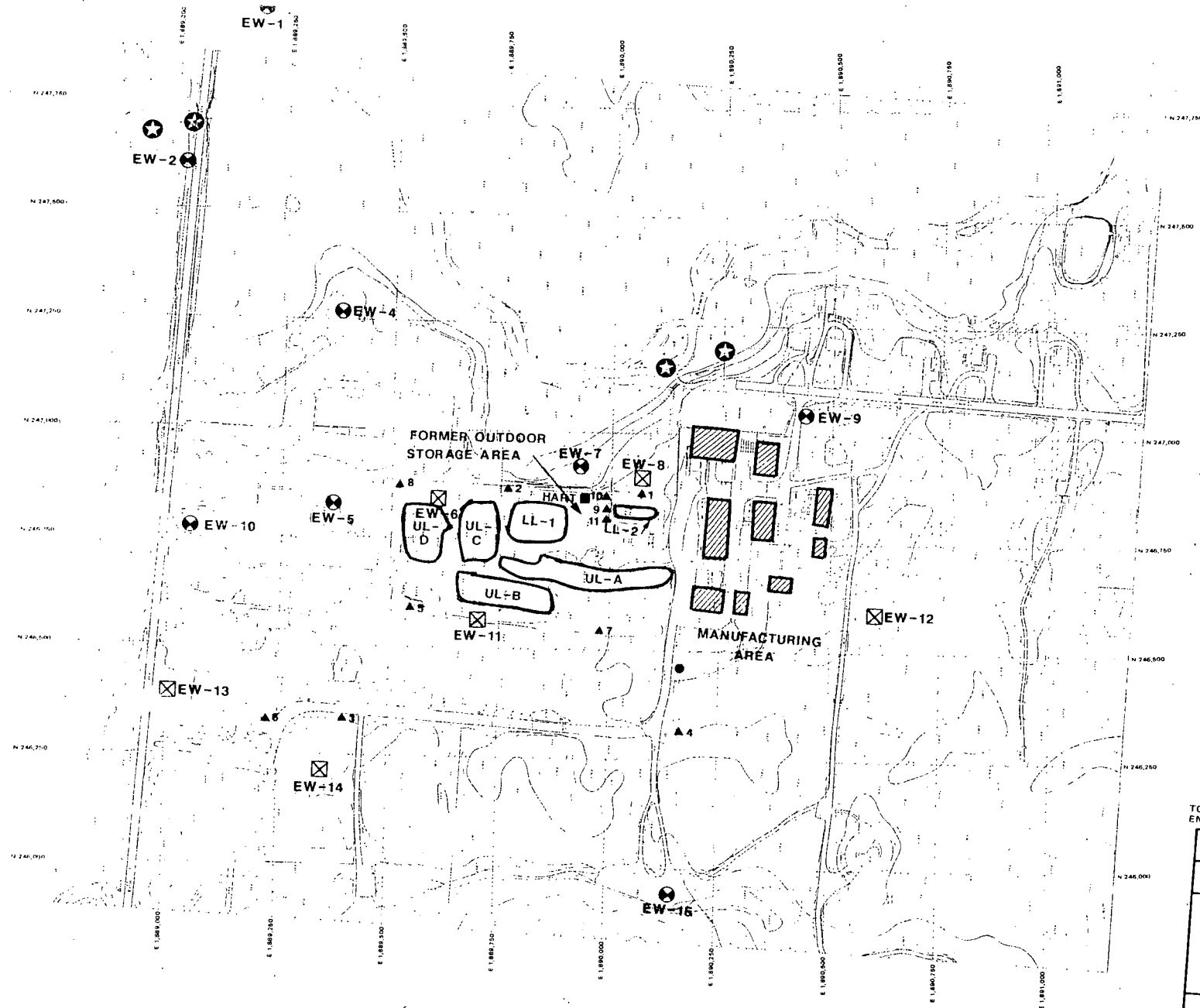
There are six lagoons on the ViChem site, two lined and four unlined. The two lined lagoons and one of the unlined lagoons, UL-A, are actively used by ViChem as part of its wastewater treatment operation. The lagoon locations are shown in Figure 2-11, and were discussed in Subsection 1.2.1. The analyses performed on the water and sediment samples are summarized in Tables 2-10 and 2-11. The analytical results from these samples are presented in Section VII of Appendix A.

Water samples were collected from the two lined lagoons during the second round of groundwater sampling on September 28, 1987. Water samples were also collected from the unlined lagoon, UL-A, at various times. Three samples were collected out of the ponded water within lagoon UL-A on July 7, 1988. An additional sample was collected directly from the treatment plant discharge pipe into this unlined lagoon on September 28, 1987. The waste stream that was cycling through the treatment plant at the time this sample was obtained is unknown.

Sediment samples were also collected from unlined lagoon UL-A at two locations. Location A was in the center of the lagoon directly south of the discharge pipe. Location B was on the south side of the lagoon approximately 200 feet west of Location A.

Soil samples were also obtained from various locations in the lagoon area. A soil boring was conducted inside dry lagoon UL-D to the water table. Surface soil samples were collected along the sides of unlined lagoons UL-A, -B, and -C. Soil borings were also drilled at locations SB-5, 6, 7, 8, and 10 to the water table. In addition to these, the soils in well borings EW-6 and EW-11 were sampled continuously to the water table when these well borings were installed.

VIN 001 0973



- TRIPLE WELL CLUSTER (8)
- ⊠ DOUBLE WELL CLUSTER (6)
- ★ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART (1)
- LL LINED LAGOON
- UL UNLINED LAGOON

SCALE IN FEET

0 100 200 300

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY ENGINEERS BY KUCERA INTERNATIONAL, J.A.

U.S. ENVIRONMENTAL PROTECT AGENCY

VINELAND CHEMICAL COMPANY

FIGURE 2-11

LAGOON SAMPLING LOCATION

EBASCO SERVICES INCORPORATED

3 OF 1986

VIN. 001 0974

4260 100 NIN

TABLE 2-10
NUMBER OF LAGOON WATER SAMPLE ANALYSES

STATION NUMBER	SAMPLE LOCATION	LAGOON LOCATION	DISSOLVED TOTAL ARSENIC	HSL POLLUTANTS				E.P. TOX	TOC
				INORGANIC	BNA	P/PCB	VOA		
UL-A	1	Unlined	1	1	1	1	1		
	2	Unlined	1	1	1	1	1		
	3	Unlined	1	1	1	1	1		
LL-2	GW2	East	2(a)	2(a)	2(a)	2(a)	2(a)		
LL-1	GW2	West	1	1	1	1	1		
UL-A	GW2	Unlined	1	1	1	1	1		
			7	7	7	7	7		

(a) Includes duplicate sample

TABLE 2-11
NUMBER OF LAGOON SEDIMENT SAMPLE ANALYSES

STATION NUMBER	BORING LETTER	SAMPLES PER BORING	LAGOON LOCATION	ASFE	GRAIN SIZE	T.O.C.	E.P. TOX
SLAG	A	3	Unlined (UL-A)	3	3	2	1
	B	3	Unlined (UL-A)	3	3	3	
		6		6	6	5	1

2.8.2 Sample Methods

Water samples from the lined lagoons were collected by lowering stainless steel buckets into the lagoons and filling the sample bottles from the buckets. The water samples from the unlined lagoon taken in July, 1987 were obtained by filling the sample containers directly from the ponded water in this lagoon except for the dissolved arsenic aliquot, which was collected in a stainless steel beaker and poured into the filter apparatus. The water sample taken from the unlined lagoon in September, 1987 was obtained by filling the bottles directly from the treatment plant discharge pipe, except for the dissolved arsenic aliquot, which was filled directly into the filter apparatus out of the discharge pipe.

The water samples from the lagoons were all analyzed for dissolved arsenic, HSL organics, and HSL inorganics. The dissolved arsenic aliquot was filtered in the field. The unfiltered HSL inorganics and dissolved arsenic aliquots were preserved in the field with nitric acid to a pH of less than 2. All samples were iced prior to shipment.

The sediment samples collected from unlined lagoon UL-A were collected with stainless steel hand augers. Samples were collected from 0-1, 1-2, and 2-3 feet below the sediment/water interface at each of the two sampling locations. Each of the six samples was homogenized in a stainless steel beaker before being placed into sample jars.

Each of the six samples were analyzed for arsenic, iron and grain size. Five of the samples were analyzed for TOC. One sample was analyzed for EP toxicity metals.

2.9 SURFACE WATER AND SEDIMENT INVESTIGATION

In Phases I and II of the field investigation for the ViChem site, sediment and surface water samples were collected from the Blackwater Branch, the Maurice River, and Union Lake. Samples were collected upstream of the ViChem plant to as far as 38 river miles downstream of the plant.

The results of the surface water and sediment investigation are discussed in detail in the River Areas RI (Ebasco, 1989c) and the Union Lake RI (Ebasco, 1989e). However, the results of the investigation at three stations on the Blackwater Branch, ER-3, ER-3A and ER-4, are discussed in this report to aid in delineating the transport of arsenic from the ViChem plant.

2.9.1 Sample Locations

Figure 2-12 shows the locations of stations ER-3, ER-3A, and ER-4. The Blackwater Branch flows east to west, therefore ER-3 is upstream of the site and ER-4 is downstream from the site.

VIN 001 0978



- SURFACE WATER AND SEDIMENT SAMPLING LOCATION
- ⊗ TRIPLE WELL CLUSTER (8)
- ⊠ DOUBLE WELL CLUSTER (6)
- ★ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART (1)

0 100 200 300
SCALE IN FEET

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SIT
FIGURE 2-12
SURFACE WATER AND SEDIMENT INVESTIGATION
EBASCO SERVICES INCORPORATED

VIN 001 0978

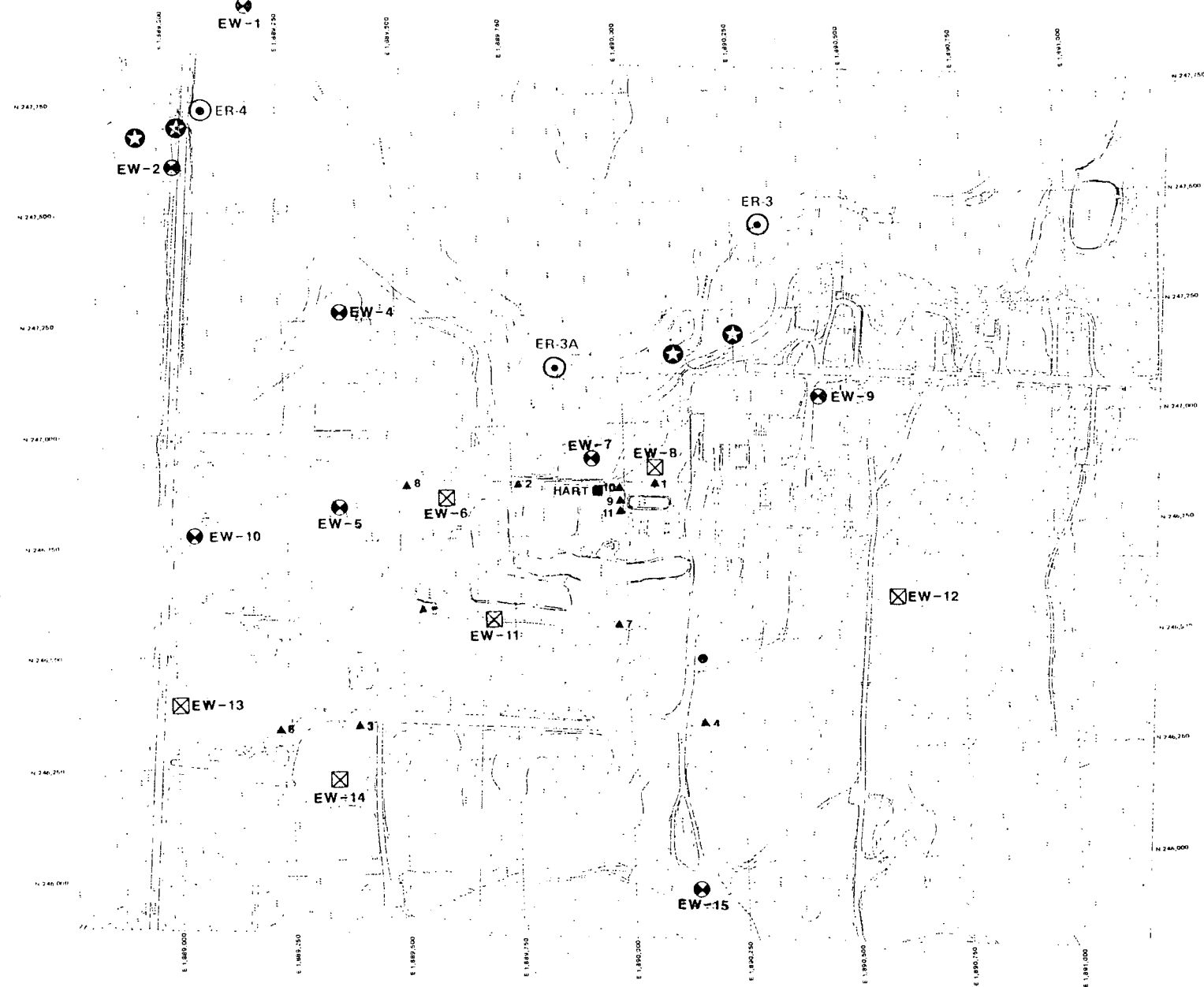


Table 2-12 lists the types of samples collected at each station in Phases I and II with the analytical results for Phase II presented in Section VIII of Appendix A.

At the time these stations were sampled in Phases I and II the Blackwater Branch was flooded as shown previously in Figure 1-5. The flooding began just downstream of the Mill Road bridge by ER-4 and extended upstream approximately to ER-3. The flooding was caused by a beaver dam located downstream of ER-4. As mentioned, the beaver dam was removed in October, 1987 in anticipation of constructing a new bridge over the Blackwater Branch on Mill Road.

2.9.2 Sample Methods

Water samples were collected from stations ER-3A and ER-4 during Phase I with a Kemmerer sampler. The sampler was lowered into the stream opened and the messenger was sent to activate the sampling device and obtain a sample of the water column. All aliquots for the various analyses listed in Table 2-12 were filled from the Kemmerer sampler.

Water samples were collected from stations ER-3, ER-3A, and ER-4 in Phase II by dipping the sample bottles directly into the stream, except for the dissolved arsenic sample aliquot. The dissolved arsenic aliquot was obtained by dipping a stainless steel beaker into the stream and filling the filter apparatus from the beaker. The sampling method was changed between Phases I and II because the Blackwater Branch is less than 2 feet deep, and because of the desire to use the minimum amount of sampling devices to avoid cross-contamination.

The water sample aliquots analyzed for dissolved arsenic were filtered in the field. These aliquots, and the unfiltered aliquots analyzed for full HSL inorganics, were preserved with nitric acid to a pH of 2 or less prior to sampling. All sample aliquots for the various analyses were iced prior to shipment.

Sediment samples were obtained from stations ER-4 and ER-3A in Phase I. The sediment samples were taken with a Wilco corer. Poor sample recovery was realized with this sampler, generally only the top foot of sediment was retained for analysis. Therefore, the sediment sampling procedure was modified for Phase II.

Sediment samples were obtained from stations ER-3, ER-3A, and ER-4 in Phase II. These samples were obtained by using a hand auger to sample sediments at depths of 0-1, 1-2, and 2-3 feet below the sediment/water interface. Two of these core type samples were obtained from each station, one on each side of the Blackwater Branch.

TABLE 2-12

SURFACE WATER AND SEDIMENT ANALYSES
BLACKWATER BRANCH
PHASE I AND II

STATION NUMBER	DESCRIPTION OF SAMPLES	ANALYSES	
		SEDIMENT SAMPLES	WATER SAMPLES
PHASE I			
ER-3	0-1 Ft. sediment, surface water	Total As, Fe, TOC	Particulate and Dissolved As and Fe
ER-4	3 colocates sediment, 3 colocates surface water	Total As, Fe, TOC	Particulate and Dissolved As and Fe HSL metals and VOAs
PHASE II			
ER-3	2 cores (0-3 ft each) 1 surface water	Total As, Fe, TOC 1 EP Tox	Dissolved As HSL organics
ER-3A	2 cores (0-3 ft each) 1 surface water	Total As, Fe, TOC 1 EP Tox	Dissolved As, HSL inorganics and organics
ER-4	3 cores (0-3 feet each) 1 surface water	Total As, Fe, TOC 1 EP Tox HSL inorganic and organic	Dissolved As, HSL inorganics and organics
Supplemental Sampling	22 borings, sampled at 2 foot intervals, from 4 to 6 feet deep	61 samples for total arsenic	

2-60

The sediments sampled in Phases I and II were removed from their sampling devices and placed into stainless steel buckets. Aliquots for volatiles analyses, if required, were taken before homogenizing the sediment. Aliquots for the remaining analyses were homogenized prior to filling the sample bottles.

In situ water quality measurements were obtained in Phases I and II. In addition, surface water flow was measured at ER-3A and ER-4 in Phase II.

2.9.3 Supplemental Sampling

Additional sediment sampling was performed in the Blackwater Branch in November, 1988. The purpose was to aid in delineating the volume of contaminated sediments remaining in the floodplain remaining after the beaver dam was breached. The sampling locations and results are discussed in detail in the River Areas RI and FS reports (Ebasco, 1989 (c) and (d)).

A total of 22 borings were conducted on an approximate 200 foot by 200 foot grid. Samples were obtained with a hand auger over approximate two foot depth intervals. Samples were obtained through the depth of sediment (black organic soil), until sand was reached. From the well installation and soil boring program discussed in Section 3.0, it was known that the natural geologic material in the area was a clean, well-sorted sand. When this material was encountered, the soil borings were terminated.

The samples were obtained using hand auger and compositing the two foot intervals by the same methods outlined above. Samples were analyzed for total arsenic.

2.10 AIR MONITORING PROGRAM

During monitoring well installation, an air sampling program was instituted to supplement the preventative measures of the site Health and Safety Plan (HASP) and to provide documentation of the relative exposures during these activities. Previous sampling during the site reconnaissance and other studies indicated that the contaminants of primary concern (from a health and safety standpoint) would be airborne (i.e., dust and arsenic).

Based upon the past studies, the amount of vegetation present, and the drilling methods that were to be employed, it was anticipated that the potential for exposure to arsenic and dusts would be low. It was decided, therefore, to conduct area sampling for arsenic and dusts on two days of each week of the monitoring well installation activities. The days to be sampled were not determined in advance in order to provide the greatest amount of flexibility in the program. This was to enable samples to be taken on the days that would provide the greatest potential for exposure and thus represent the "worst case" situations.

Although arsenic and dusts were the main concern for the air sampling program, real-time instruments were also used routinely to monitor the ongoing work conditions for organic vapors and explosive gases. Readings from the monitoring instruments were recorded in the site Health and Safety log books.

2.10.1 Sample Locations

Week-to-week flexibility was required in choosing when and where the air samples were to be taken. Because a well installation program can experience delays or acceleration and weather patterns can change rapidly, this flexibility was necessary to assure that the days/locations sampled would be representative of worst case exposures. Therefore, the sample locations were determined each week, based on a number of factors.

The factors that were taken into consideration when choosing which days/locations were to be sampled included:

- o Well location (wells to be installed in and around the lagoon area were targeted for top priority);
- o Current and forecasted weather (dry, hot, windy conditions were preferred);
- o Past weather (previous rainfall may reduce dust generation); and
- o Activities scheduled (the first steps during well installation pose greatest potential for dust generation).

A number of the samples were collected in and around the lagoon area. Other areas that were sampled include the inside of Building 9, near the chicken coops, near the Blackwater Branch, and at the well location EW-1 that was to serve as the background location.

Table 2-13 presents the air sampling results.

2.10.2 Sampling Methods

All samples were collected in accordance with established NIOSH (National Institute for Occupational Safety and Health) methods, and were shipped in accordance with EPA's Contract Lab Program procedures to document their chain-of-custody. The NIOSH methods utilized for sample procurement and specified for sample analyses are Method 0500 for total dusts, Method 0600 for respirable dusts, and Method 7900 for arsenic and organic compounds.

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001
0982

TABLE 2-13
AIR SAMPLING RESULTS

<u>DATE</u>	<u>WELL LOCATION</u>	<u>TOTAL AS</u> ⁽¹⁾	<u>TOTAL DUST</u> ⁽²⁾	<u>TOTAL RESPIRABLE DUST</u> ⁽²⁾
5-12-87	EW-5D	0.1 (u)	1.6 (u)	0.2 (u)
5-14-87	Decon Pad	0.1 (u)	1.7 (u)	0.3 (u)
5-28-87	EW-14	0.1 (u)	1.5	0.2
5-29-87	EW-15	0.2 (u)	1.6 (u)	0.5
6-2-88	EW-12	0.001 mg*	0.24 ⁽³⁾ *	0.32 ⁽³⁾ *
6-4-87	Decon Pad	0.001 mg*	0.12 ⁽³⁾ *	0.19 ⁽³⁾ *
6-10-87	EW-7	0.1 (u)	2.4 (u)	0.4
6-11-87	EW-1	0.11 (u)	1.6 (u)	0.3
6-16-87	EW-6	0.1 (u)	1.6	1.0
6-18-87	EW-2	0.09 (u)	1.6 (u)	1.0
6-18-87	EW-2	0.09 (u)	1.6 (u)	1.0
6-23-87	EW-4	0.001 mg*	-0.7 ⁽³⁾ *	-0.64 ⁽³⁾ *
6-25-87	Bld. #9	0.001 mg*	-0.62 ⁽³⁾ *	-0.55 ⁽³⁾ *
6-30-87	EW-11M	0.001 mg*	-0.65 ⁽³⁾ *	-0.49 ⁽³⁾ *
7-1-87	EW-11S	0.001 mg*	-0.5 ⁽³⁾ *	-0.52 ⁽³⁾ *
5-12-87	Blanks	0.1 mg (u)	0.2 mg (u)	0.2 mg (u)

(1) mg/m³, unless otherwise noted

(2) mg/m³, unless otherwise noted

(3) Post sample weight in mg, filter is subtracted

(u) Below detectable limit

* Sample invalidated

Because the number of samples that were to be taken was limited, it was decided to take area samples rather than personnel samples. To help assure that the samples would be representative of the work areas, the sampling pumps were located as close as practical to the point of operation, on the downwind side and elevated so as to be at a height of approximately 5.5 feet.

The pumps were pre- and post-calibrated on each day's use, using a representative filter-cassette in the calibration train.

2.10.3 Air Sample Results

The following table lists the allowable exposure limits applicable to the air sampling performed at ViChem during May, June and July, 1987.

	<u>As</u>	<u>Total Nuisance Dusts</u>	<u>Respirable Dusts</u>
OSHA(1)	.5 mg/m ³	15 mg/m ³	5 mg/m ³
ACGIH(2)	.2 mg/m ³	10 mg/m ³	*

(1) Occupational Safety and Health Administration

(2) American Conference of Governmental Industrial Hygienists, 1987-1988

*No exposure limit established.

When this is compared to the results given in Table 2-13, it can be seen that in all cases the amounts of dust and airborne arsenic were well below the allowable exposure limits. The information provides a quantitative measurement of the personnel's working environment. Examining the data from this perspective, it can be determined that personnel involved in the installation of monitoring wells did not receive exposures to these contaminants in excess of the applicable regulations.

2.11 QUALITY ASSURANCE AND QUALITY CONTROL

2.11.1 Decontamination Procedures

To ensure that chemical analysis results were reflective of the actual concentrations present at sampling locations, equipment involved in sampling activities was decontaminated. Decontamination was also performed to minimize the potential for cross-contamination between sampling locations and the transfer of contamination off-site.

All equipment was decontaminated prior to drilling, excavation and sampling activities. Such equipment included drilling rigs, downhole tools, augers, well casings and screens, split spoons, bailers, and water level indicators.

Prior to drilling or leaving the site, large equipment, not directly utilized for sampling, was decontaminated by steam cleaning at the decontamination pad. Such equipment included the drill rigs, augers, well casings, rods and screens.

Prior to sampling all equipment such as split spoons, bailers, bailer wires, spoons and all surface water and sediment sampling equipment was decontaminated using the following procedures:

- o Alconox or liquid detergent wash
- o Potable water rinse
- o Nitric acid rinse
- o Potable water rinse
- o Acetone rinse
- o Distilled/deionized water rinse

After cleaning, small equipment was wrapped in tin foil or butcher paper to minimize contamination prior to utilization.

The probe and cable of water level indicators were decontaminated using distilled/deionized water. Field monitoring equipment such as volatile organic analyzers and combustible gas meters was wiped down with clean paper towels.

2.11.2 QA/QC Samples

A trip blank was prepared for each day of field sampling when samples for volatiles analyses were taken in advance of initiating the sampling on that day. The trip blank was filled with deionized, organic free water and was used to determine if any cross-contamination occurred between samples during shipment. The trip blanks were analyzed for volatiles only. Trip blank analytical results are presented in Section X of Appendix A.

A field blank was taken for each media sampled at a frequency of approximately one field blank per 20 samples. The field blank was filled with deionized, organic free water that was used to rinse the field sampling equipment after decontamination. Field blank analytical results are presented in Section IX of Appendix A.

A duplicate sample was obtained at a frequency of approximately one duplicate for each set of 20 samples of a similar matrix. The results of the duplicate sample analyses provide information concerning sample homogeneity, analytical precision and accuracy and the effect of the sample matrix on the analytical methodology.

2.11.3 Field Audits

Several audits were performed to determine that the field work was conducted within the procedures presented in the approved FOP for the site and in accordance with accepted USEPA and NJDEP protocols. Audits and/or inspections were performed by the following personnel on the following days:

<u>DATE</u>	<u>COMPANY/AGENCY</u>
6/25/86	Ebasco QA (Phase I)
5/5/87	NJDEP
5/13/87	NJDEP
5/14/87	Ebasco QA
5/27/87	USEPA
6/2/87	USEPA
7/1/87	USEPA
7/16/87	Ebasco QA

2.11.4 Data Validation

Data Quality Objective (DQO) Level 4 analyses were performed by the CLP laboratories for this RI/FS. This is the highest level of analytical QA/QC, designed to provide data of the highest quality.

Only analytical data that withstood this rigorous QA/QC procedure, that is only data which were not rejected in the validation process, were considered valid and usable for this RI/FS. Throughout this report and in the Appendices, an analysis marked with an "X" was rejected. This analysis was therefore not used to draw conclusions about contaminant concentrations, and did not factor into calculated averages and means.

Owing to the large size of the analytical data base for the RI/FS, the reason for rejecting an individual analysis is not reported here. This information is available and can be provided if requested.

JIN 001 0987

3.0 PHYSICAL CHARACTERISTICS OF STUDY AREA

3.1 SITE GEOLOGY AND SUBSURFACE FEATURES

3.1.1 Regional Setting

The ViChem site is located in the Atlantic Coastal Plain geomorphic province. The area is characterized geologically by a thick sequence of Cretaceous to Recent age sediment (sand, gravel, silt and clay) which overlies the bedrock basement; the bedrock surface is inclined gently toward the southeast. The sediment, primarily marine and nearshore fluvial clastics, forms a stratigraphic wedge estimated to be from 2,500 feet thick in the northwestern part of the county to 4,500 feet thick in the southeastern part of the county (Walker, 1983).

The major stratigraphic units are presented in Table 3-1 and a representative cross-section of the stratigraphic wedge is shown in Figure 3-1. The dip of the stratigraphic units is on the order of 1-2 degrees toward the southeast.

3.1.2 Stratigraphy

The ViChem site is immediately underlain by a sequence of sand units, with local clayey and silty interbeds. The sediment is correlated with the Cohansey and possibly upper Kirkwood formations, both of Miocene age.

Although the Kirkwood and Cohansey can be mapped in outcrop, the distinctions between the two units are not always clear (Isphording and Lodding, 1969). Facies changes within the formations, as well as the transitional contact between the formations, have contributed to the problem of identifying the contact. This is especially true in the subsurface.

As a practical matter, the formal stratigraphic names have little bearing on the geology beneath the ViChem plant site. It was, however, convenient to define four informal stratigraphic units during the progress of this RI. The unit subdivisions are based on sample descriptions and on borehole gamma logs. Split spoon samples, obtained at 2- to 5-foot intervals, provided discrete sampling points throughout the boreholes, while the gamma logs provided a continuous stratigraphic record of the boreholes to help identify geologic contacts and to establish a correlation between the boreholes. The sediments are grouped on the basis of overall similarities, but they are characterized by variability, both in samples and gamma response.

IN 100 0986

SYSTEM	FORMATION	MAXIMUM REPORTED THICKNESS	LITHOLOGY	WATER-BEARING CHARACTERISTICS
Quaternary	Alluvial deposits	80	Sand, silt, and black mud.	Locally may yield small quantities of water to shallow wells.
	Beach sand and gravel		Sand, quartz, light-colored, medium grained, pebbly.	
	Cape May Formation	200	Sand, quartz, light-colored, heterogeneous, clayey, pebbly, glauconitic.	Thicker sands are capable of yielding large quantities of water.
Tertiary	Pensauken Formation	40	Gravel, quartz, light-colored, sandy.	No known wells tap this formation.
	Bridgeton Formation			
	Beacon Hill Formation	250	Sand, quartz, light-colored, medium to coarse-grained, pebbly; local clay beds.	A major aquifer. Ground-water occurs generally under water-table conditions. In Cape May, the aquifer is under artesian conditions. Inland from the coast and in the northern part of Ocean County, the upper part of the Kirkwood Formation is in hydraulic connection with the Cohansey Sand.
	Cohansey Sand	780	Sand, quartz, gray to tan, very fine- to medium-grained, micaceous, and dark-colored diatomaceous clay.	Includes two aquifers. The principal artesian aquifer along the Atlantic Coast is the lower aquifer or the Atlantic City "800-foot" sand. The upper aquifer is artesian in Cape May. In the Atlantic City area it is also artesian but thin (10-20 feet) and not presently being used. Inland from the coast and in the northern part of the coast in Ocean County, the upper aquifer consists of the upper part of the Kirkwood Formation and the Cohansey Sand. Locally may be under semiarartesian or artesian conditions.
	Piney Point Formation	220	Sand, quartz and glauconitic, fine- to coarse-grained.	Minor aquifer in New Jersey. Greatest thickness in Cumberland County.
	Shark River Marl	1407	Sand, quartz and glauconite, gray, brown, and green, fine- to coarse-grained, clayey, and green silty and sandy clay.	Locally may yield small quantities of water to wells.
	Manasquan Formation	180	Sand, quartz, gray and green, fine- to coarse-grained, glauconitic, and brown clayey, very fossiliferous, glauconite and quartz calcarenite.	Locally may yield small to moderate quantities of water to wells.
	Vincetown Formation	100	Sand, quartz, gray and green, fine- to coarse-grained, glauconitic, and brown clayey, very fossiliferous, glauconite and quartz calcarenite.	Locally may yield small to moderate quantities of water to wells.
	Normerstown Sand	35	Sand, glauconite, green, medium- to coarse-grained, clayey.	Locally may yield small quantities of water to wells.
	Zinton Sand	25	Sand, quartz, and glauconite, brown and gray, fine- to coarse-grained, clayey, micaceous.	No known wells tap this sand.
Cretaceous	Red Bank Sand	150	Sand, quartz, and glauconite, brown and gray, fine- to coarse-grained, clayey, micaceous.	Yields small quantities of water to wells in Monmouth County.
	Navesink Formation	50	Sand, glauconite, and quartz, green, black, and brown, medium- to coarse-grained, clayey.	Locally may yield small quantities of water to wells.
	Mount Laurel Sand	220	Sand, quartz, brown and gray, fine- to coarse-grained, glauconitic.	A major aquifer in the northern part of the Coastal Plain. A sand unit within the two formations forms a single aquifer.
	Wenonah Formation		Sand, quartz, gray and brown, very fine- to fine-grained, glauconitic, micaceous.	
	Marsannettown Formation	30	Sand, quartz and glauconite, gray and black, very fine to medium-grained, very clayey.	Leaky confining bed.
	Englishtown Formation	220	Sand, quartz, tan and gray, fine- to medium-grained; local clay beds.	A major aquifer in the northern part of the Coastal Plain. Two aquifer units in Ocean County.
	Woodbury Clay	325	Clay, gray and black, micaceous.	The two formations form a major confining unit throughout the New Jersey Coastal Plain. Locally the Merchantville may yield small quantities of water to wells.
	Merchantville Formation		Clay, gray and black, micaceous, glauconitic, silty; locally very fine-grained quartz and glauconitic sand.	
	Magothy Formation	4100	Sand, quartz, light-gray, fine-grained, and dark-gray lignitic clay.	Major aquifer system in New Jersey Coastal Plain. In the northern part of the Coastal Plain, two aquifers have been defined. These are the Farrington aquifer (mainly Raritan age) and the Old Bridge aquifer (Magothy age).
	Arcadia Formation		Sand, quartz, light-gray, fine- to coarse-grained, pebbly, arkosic, red, white, and variegated clay.	
	Potomac Group		Alternating clay, silt, sand, and gravel.	
Pre-Cretaceous	Pre-Cretaceous Unconsolidated rocks and Wissahickon Formation	7	Precambrian and lower Paleozoic crystalline rocks, metamorphic schist and gneiss; locally Triassic basalt, sandstone, and shale.	Except along Fall Line, no wells obtain water from these consolidated rocks.

Source: Vowinkel, E.F., and Foster, W.K., 1981, *Hydrogeologic Conditions in the Coastal Plain of New Jersey*, U.S. Geol. Sur., Open File Rpt. 81-405.

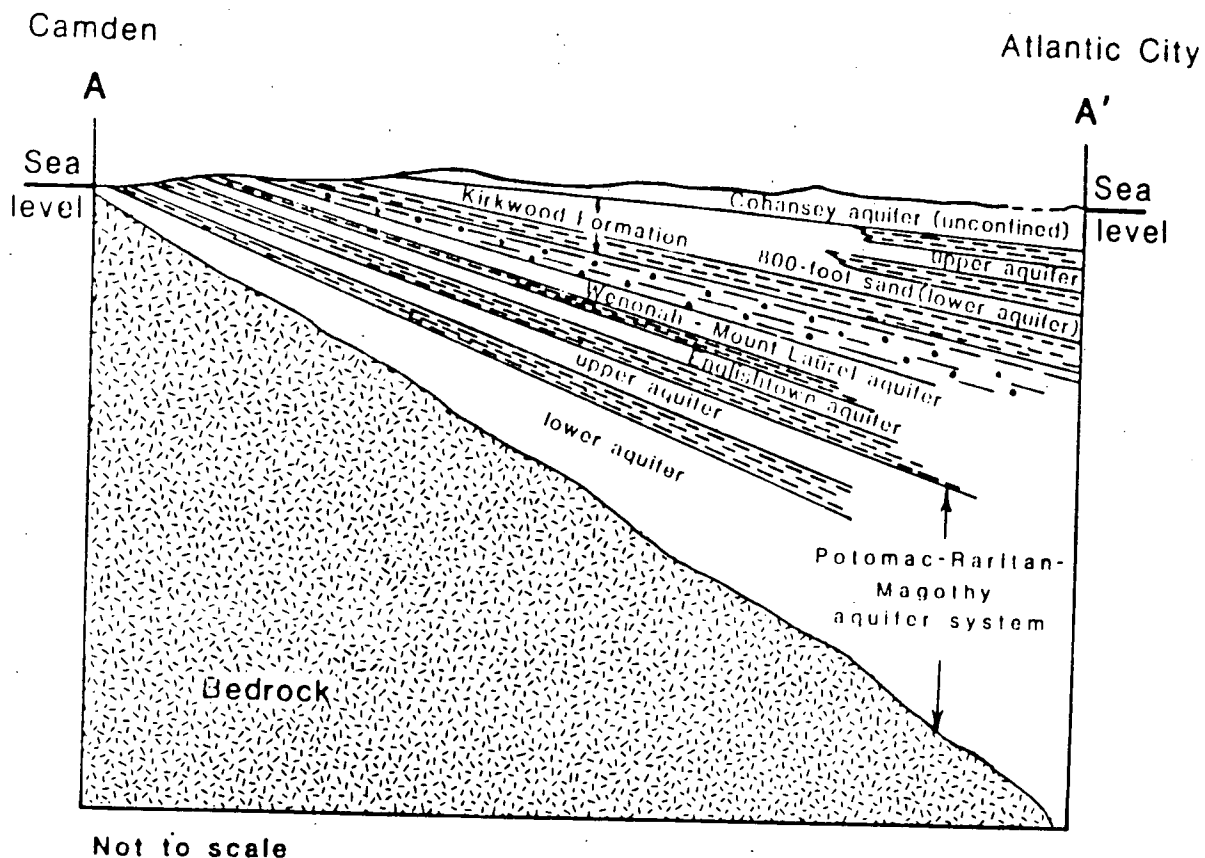
U.S. ENVIRONMENTAL PROTECTION AGENCY

VINELAND CHEMICAL COMPANY

TABLE 3-1
MAXIMUM THICKNESS, LITHOLOGY
WATER-BEARING CHARACTERISTIC
GEOLOGIC FORMATIONS OF THE
COASTAL PLAIN OF NEW JERSEY

EBASCO SERVICES INCORPORATED

001 0689




Source: Prepared in cooperation w/NJDEP
Div. of Wtr. Resources, 1983

U.S. Geol. Survey
Water Resources Investigation Report
82-4077

RICHARD L. WALTER
Evaluation of Water Levels in
Major Aquifers of the New Jersey
Coastal Plain, 1978

EXPLANATION

 Composite confining layer
and minor aquifer

 Confining layer

U.S. ENVIRONMENTAL PROTECTION
AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 3-1

DIAGRAMMATIC HYDROGEOLOGIC SECTI
OF THE NEW JERSEY COASTAL PLAIN

EBASCO SERVICES INCORPORATE

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Figure 3-2 shows the locations of three cross-sections which display the four stratigraphic units found on site. Table 3-2 provides pertinent depth and elevation information from the drilling program. The cross-sections are shown in Figures 3-3 through 3-5. The stratigraphic units are described below.

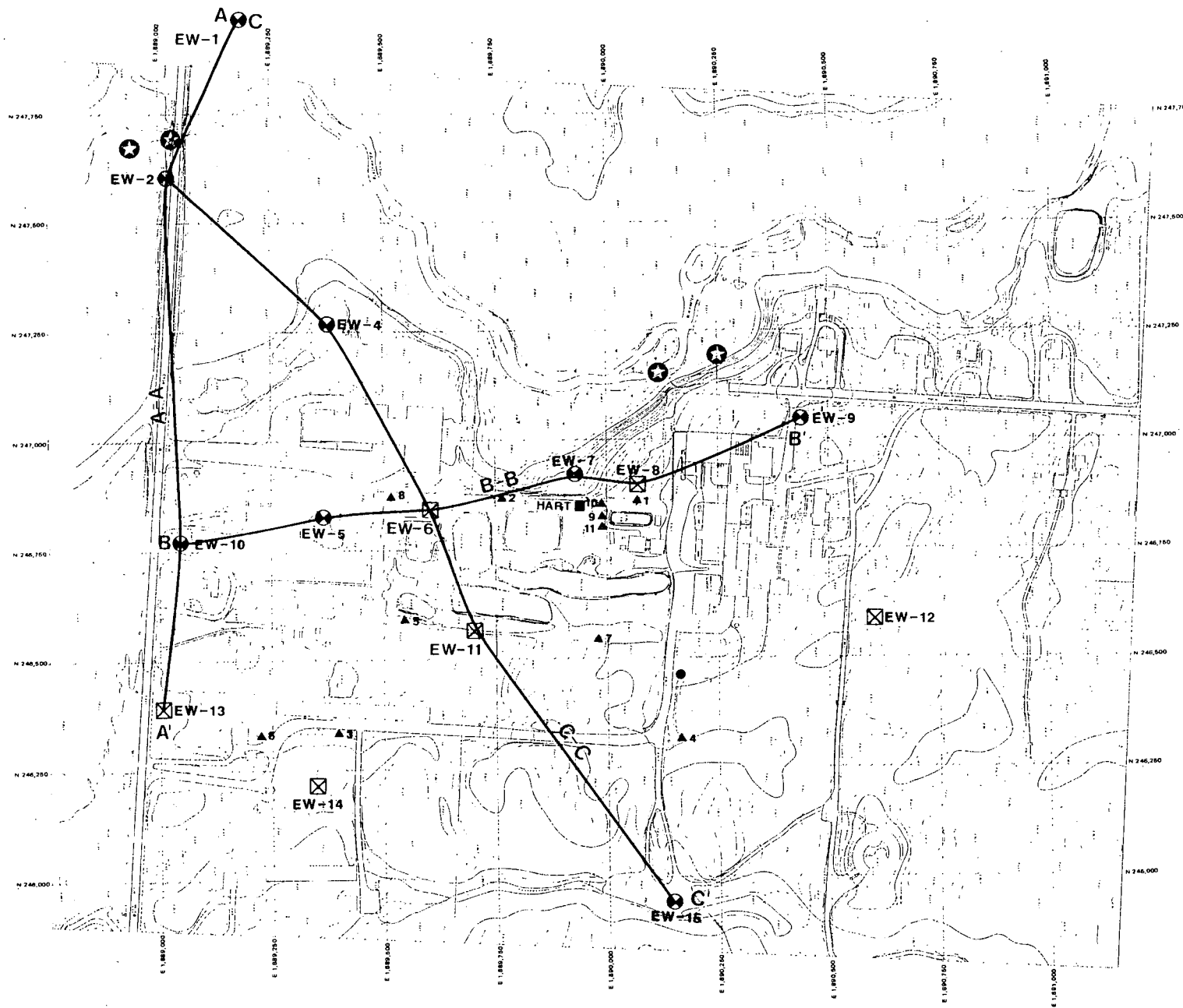
Upper Sand - Generally, the upper sand is a medium to coarse-grained, well-washed, poorly graded sand. Some gravel lenses are present locally. The unit is usually light brown in color, but can vary locally to dark brown, orange brown to red-purple, and gray. The upper sand varies in thickness from approximately 40 to 80 feet, thickening to the southeast, consistent with the southeasterly regional dip.

Banded Zone - The banded zone is an interval of interbedded clastics, fine-medium sand, silt, clay, and mixtures of these materials. The unit has well defined bedding laminations. Color varies; commonly the sediment is light to medium brown, although darker brown and gray colors are also present. The banded zone varies in thickness from about 12 to 25 feet, being thickest in the northwest part of the site. Individual layers within the unit appear to be discontinuous.

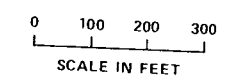
Middle Sand - The middle sand is a medium-fine grained, relatively dense sand with thin clay laminae throughout. The unit is generally light to medium brown or light gray in color. The thickness of the middle sand is fairly consistent, ranging from about 32 to 40 feet within the site area.

Lower Sand - The lower sand is a medium to fine-grained, relatively dense, sand unit. The top of the unit is marked by a thin (1 to 2 feet), distinctly black to dark gray clayey interval. The clayey interval is relatively consistent throughout the site, but it is not clearly present in all boreholes. The dark gray material has a fetid sulfide odor and is believed to represent natural organic material, perhaps stagnant lagoon deposits; it is generally found within 5 to 10 feet of the top of the lower sand. In most cases, the deeper holes of the current investigation were terminated in either the clayey interval or in dark gray sands of the lower sand unit. One borehole, EW-5, however, was advanced about 25 feet beneath a 10 foot dark gray to black zone at the top of the lower sand, encountering light gray to brown sand and silt, similar to those of the middle sand.

VIN 001 0992



- TRIPLE WELL CLUSTER (8)
- ⊠ DOUBLE WELL CLUSTER (6)
- ★ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART (1)



TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORP. ENGINEERS BY KUCERA INTERNATIONAL, JANUARY

U.S. ENVIRONMENTAL PROTECTION AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 3-2.
CROSS SECTIONS
A-A'
B-B'
C-C'

EBASCO SERVICES INCORPORATED

VIN 001 0992

TABLE 3-2
STRATIGRAPHIC INFORMATION

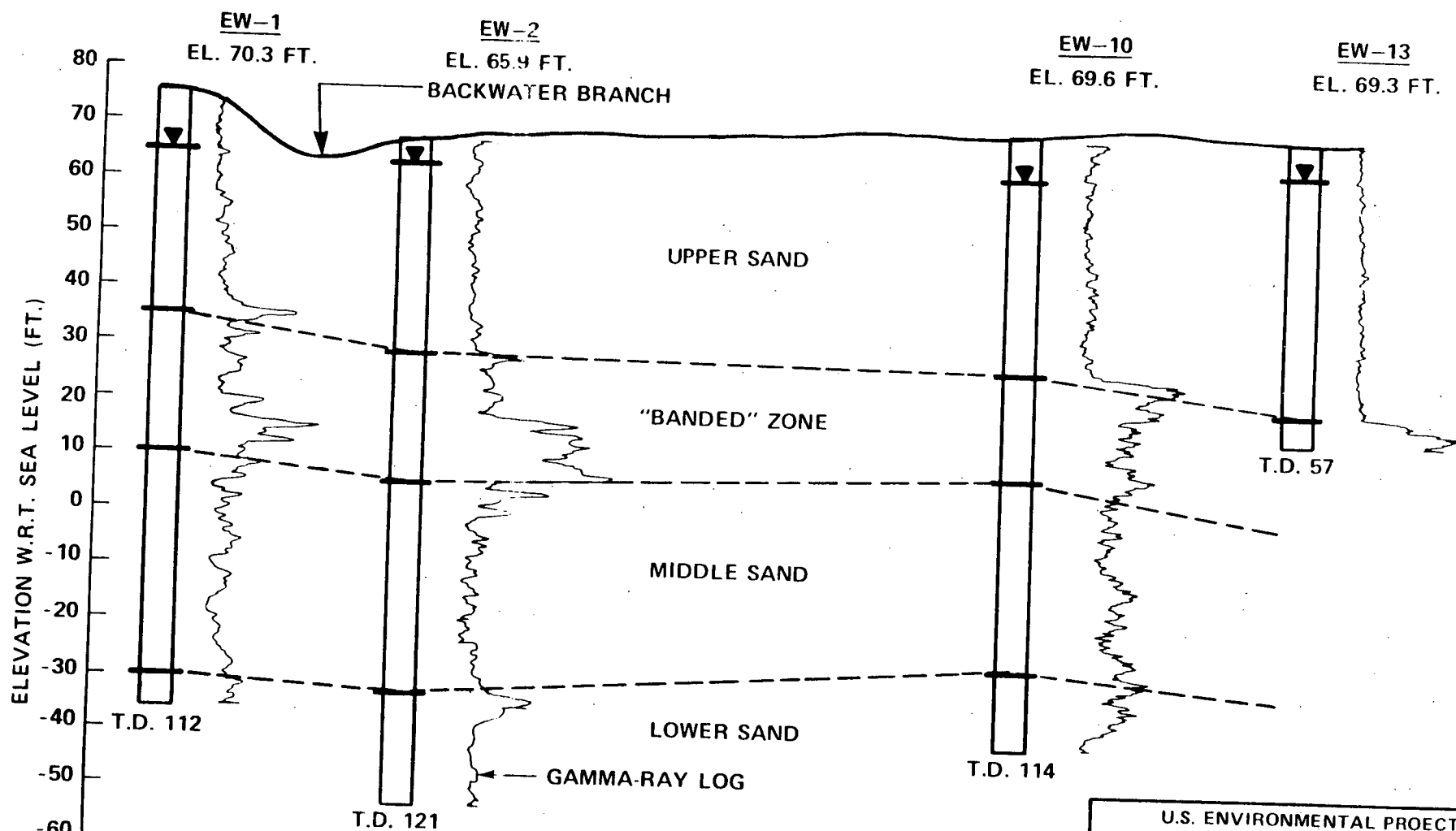
Well Cluster	El. (Grnd)	Depth of Boring	Top Lower Sand	Top Gray	Top Banded Zone	El. Bottom of Boring	El. Lower Sand	El. Gray	Diff.	El. Banded Zone	Depth of Gamma-Ray Log
EW-1	70.3	112.0	102.0	101.0	38.0	-41.7	-31.7	30.7	1.0	32.3	106.5
EW-2	65.9	121.0	96.0	97.0	38.0	-55.1	-30.1	-31.1	-1.0	27.9	118.0
EW-4	72.0	117.0	92.0	100.0	44.0	-45.0	-20.0	-28.0	-8.0	28.0	112.0
EW-5	69.8	136.0	108.0	100.0	50.0	-66.2	-38.2	-30.2	8.0	19.8	130.0
EW-6	72.7	62.0	n/a	n/a	58.0	+10.7	n/a	n/a	n/a	14.7	60.0
EW-7	70.4	127.0	110.0	115.0	62.0	-56.6	-39.6	-44.6	-5.0	8.4	115.0
EW-8	75.9	72.0	n/a	n/a	>72.0	-3.9	n/a	n/a	n/a	< 3.9	n/a
EW-9	78.6	127.0	125.0	126.0	77.0	-44.4	-46.4	-47.4	-1.0	1.6	126.0
EW-10	69.6	114.0	95.0	112.0	42.0	-48.4	-25.4	-42.4	-17.0	27.6	106.0
EW-11	75.0	67.0	n/a	n/a	66.0	+ 8.0	n/a	n/a	n/a	9.0	69.0
EW-12	75.9	72.0	n/a	n/a	>72.0	+ 3.9	n/a	n/a	n/a	< 3.9	n/a
EW-13	69.3	57.0	n/a	n/a	50.0	+12.3	n/a	n/a	n/a	19.3	55.0
EW-14	67.3	62.0	n/a	n/a	>62.0	+ 5.3	n/a	n/a	n/a	< 5.3	53.0
EW-15	70.7	117.0	115.0	116.0	69.0	+46.3	-44.3	-45.3	-1.0	1.7	114.0

Elevations given are relative to Mean Sea Level (MSL)

7769b

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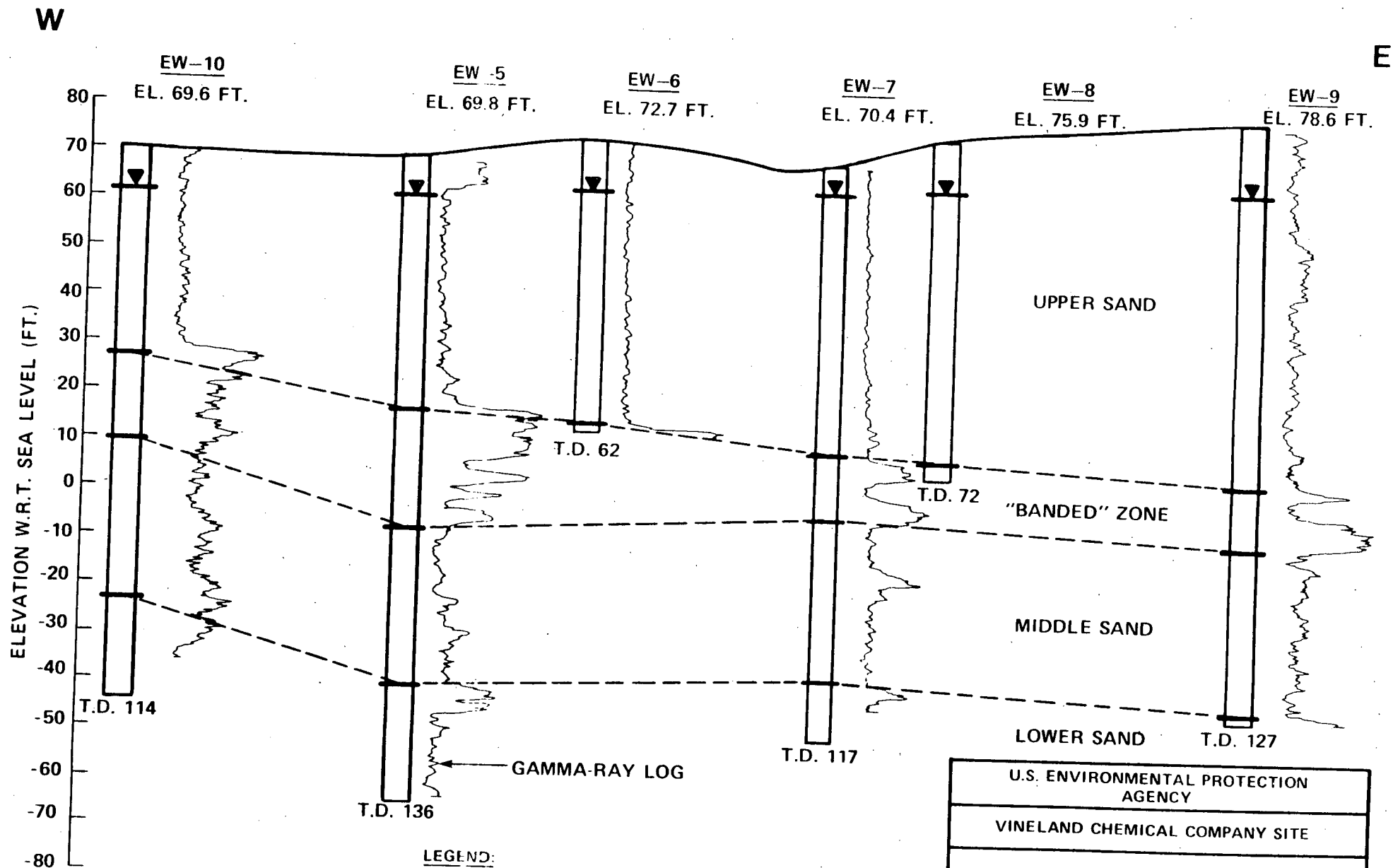
S



LEGEND:

- ▼ WATER TABLE MEASURED ON 11/12/87 IN SHALLOW WELLS
- VERTICAL EXAGGERATION APPROXIMATELY 7X
- OVERALL LENGTH OF SECTION IS 1430 FEET
- SEE FIGURE 3.2 FOR MAP LOCATION OF SECTION

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-3 GEOLOGIC CROSS-SECTION A-A'
EBASCO SERVICES INCORPORATED

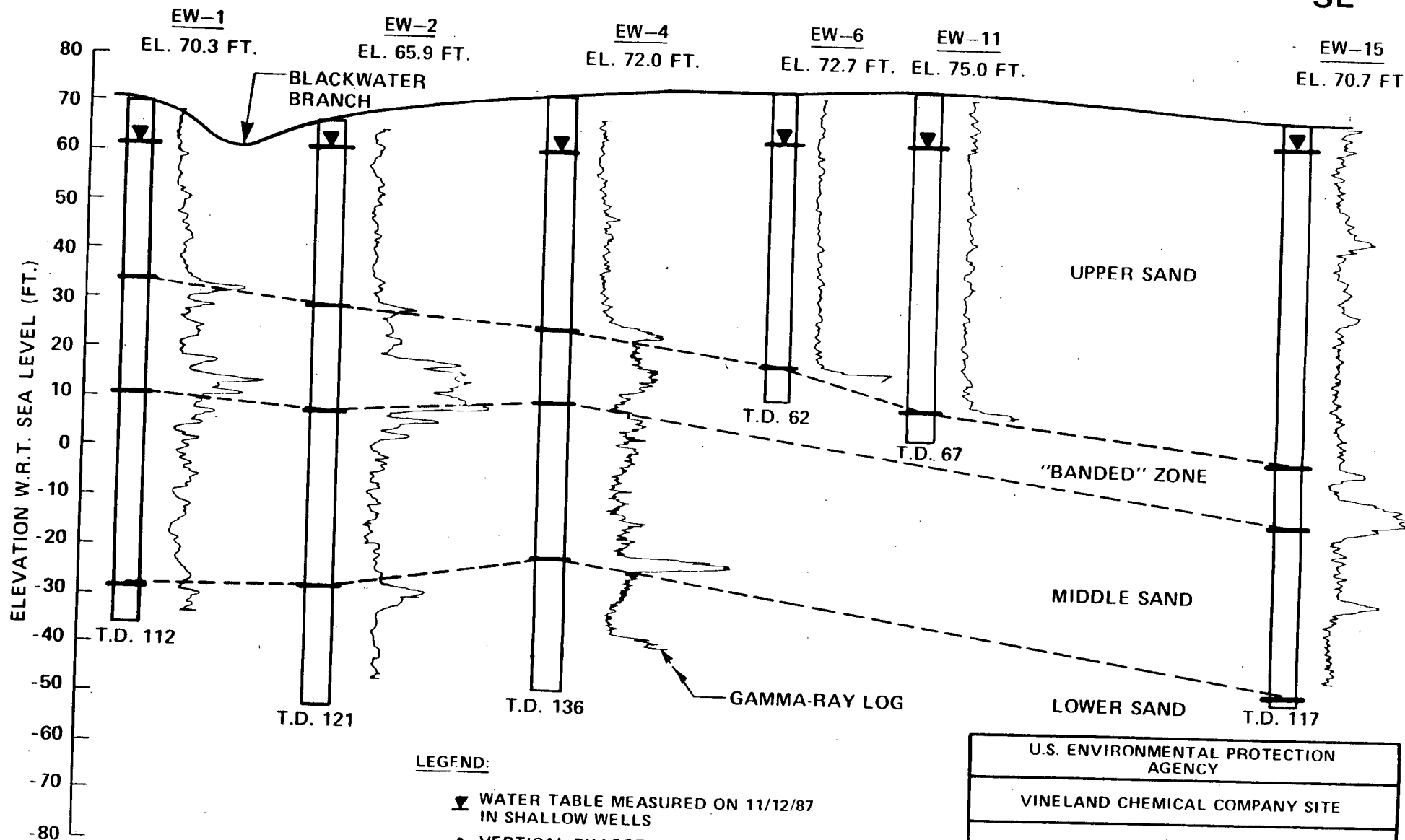


- ▼ WATER TABLE MEASURED ON 11/12/87
IN SHALLOW WELLS
- VERTICAL EXAGGERATION APPROXIMATELY 6X
- OVERALL LENGTH OF SECTION IS 1340 FEET
- SEE FIGURE 3-2 FOR MAP LOCATION OF SECTION

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-4 GEOLOGIC CROSS-SECTION B-B'
EBASCO SERVICES INCORPORATED

NW

SE



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VINELAND CHEMICAL COMPANY SITE
FIGURE 3-5
GEOLOGIC CROSS-SECTION C-C'
ERASCO SERVICES INCORPORATED

3.1.3 Structure

The basic structural framework of the coastal plain is dominated by the southeast dip of the basement surface. The basement rock is believed to be primarily a Precambrian metamorphic complex which has been eroded to a relatively flat surface, then tilted to the southeast as shown in Figure 3-6. The bedrock gradient or dip is approximately 100 feet per mile [approximately 1 degree (Vowinkel and Foster, 1981)].

Structural features within the sedimentary wedge that lies above the basement surface are related principally to erosional or topographic influences within the sedimentary units. Differential compaction of some units may also lead to local downwarping, but in general, structures such as faults or sharp folds are quite rare within the coastal plain sediments.

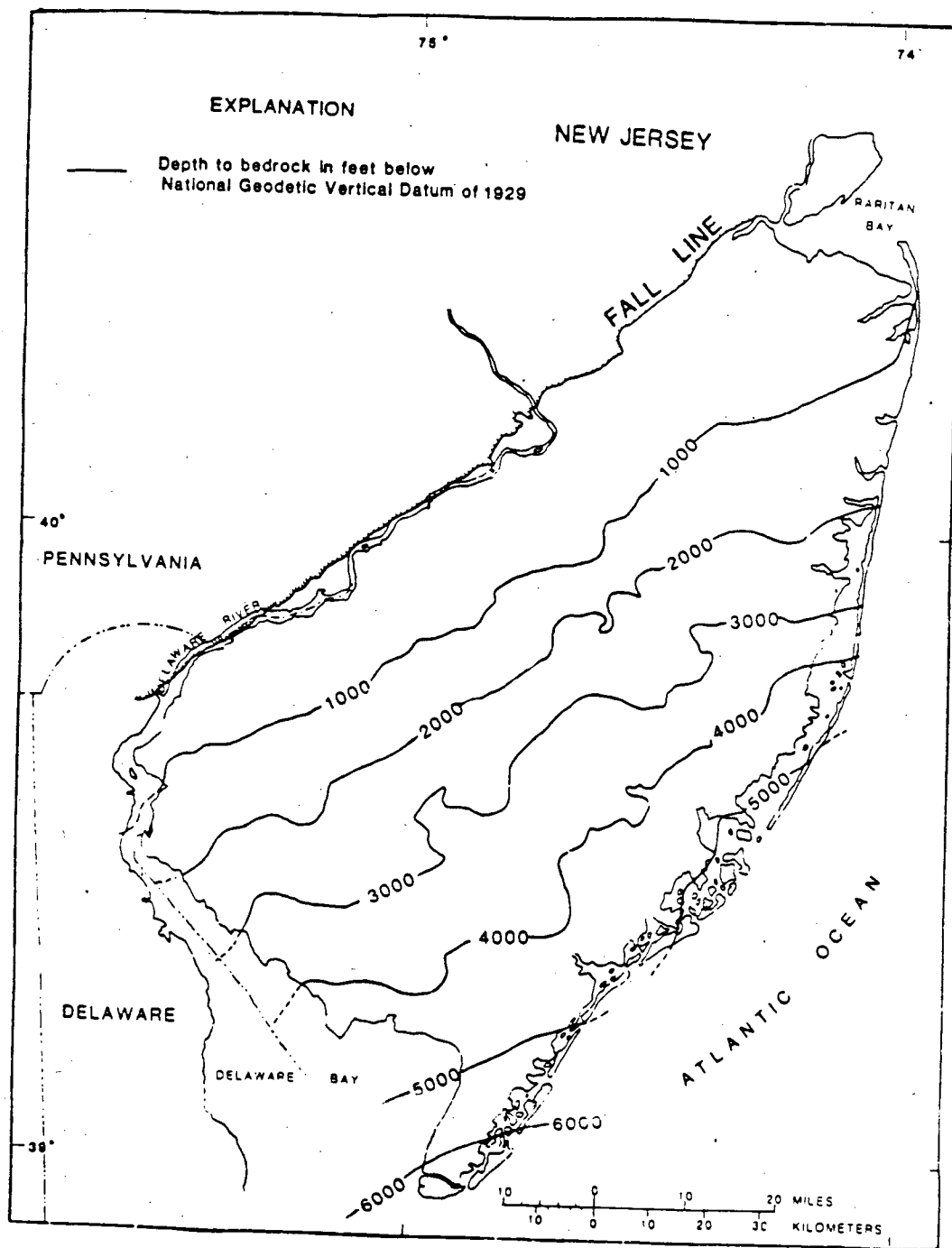
Within the ViChem site, the dominant southeasterly dip is evident from borehole data, and mapping indicates the presence of local highs and lows superimposed on the regional dip. This can be seen on the accompanying cross sections as well as Figure 3-7 depicting the base of the upper sand, and Figure 3-8, which shows minor relief on top of the lower sand. The data suggest dip values of 0.5 to 2 degrees within the site area. There is no indication of sharp folding or faulting in the site area.

3.2 GEOPHYSICAL INVESTIGATION

3.2.1 Survey Results

Apparent terrain conductivity data for the areas identified in Figure 2-4 are presented in Figures 3-9 to 3-14 as contour maps. As illustrated on these figures, EM data observed over most of the site are generally low and uniform, suggesting that at least in the near surface the highly permeable sands may have been flushed of arsenic salts by surface recharge. Most of the observed variations of terrain conductivity are within the range of background values established for the site or are attributed to cultural interference. However, after filtering for apparent cultural noise, slightly elevated EM values were observed between the lagoons and the Blackwater Branch floodplain immediately to the north within Area 3 (Figure 3-10), and in the adjacent portions of Area 5. In addition, slightly elevated EM values were also recorded within Area 6 (Figure 3-13), in the general vicinity of the old chicken coops by well cluster EW-14, where a spill may have occurred in the past.

Another anomaly of interest is the intense conductivity high evident in Area 4 near well EW-13 (Figure 3-11). This anomaly probably reflects the occurrence of a buried storage tank or a reinforced septic tank and is probably not due to arsenic salts.



VOWINKEL, E. F., AND FOSTER, W. K., 1981. HYDROGEOLOGIC
CONDITIONS IN THE COASTAL PLAIN OF NEW JERSEY. U.S.
GEOLOGICAL SURVEY OPEN FILE REPORT 81-405.

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VINELAND CHEMICAL COMPANY SITE

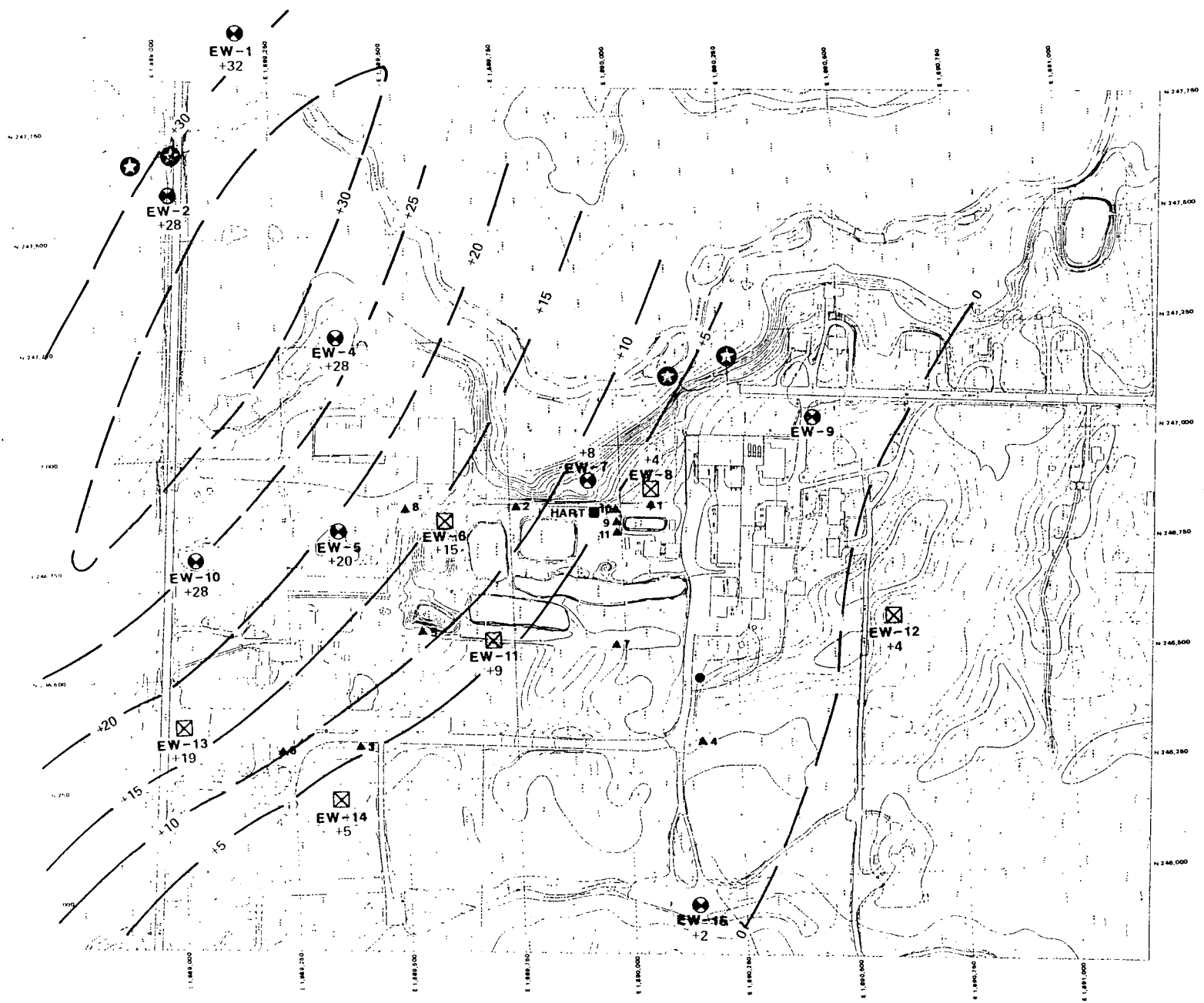
FIGURE 3-6

GENERALIZED CONFIGURATION
OF PRE-CRETACEOUS BEDROCK SURFACE
BELOW THE COASTAL PLAIN
OF NEW JERSEY

EBASCO SERVICES INCORPORATED

8 660 T00

VJN 001 0999



- TRIPLE WELL CLUSTER (8)
- ⊠ DOUBLE WELL CLUSTER (6)
- ★ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART (1)

5' CONTOUR INTERVAL
0 100 200 300
SCALE IN FEET

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CO
ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1971

U.S. ENVIRONMENTAL PROTECTION
AGENCY

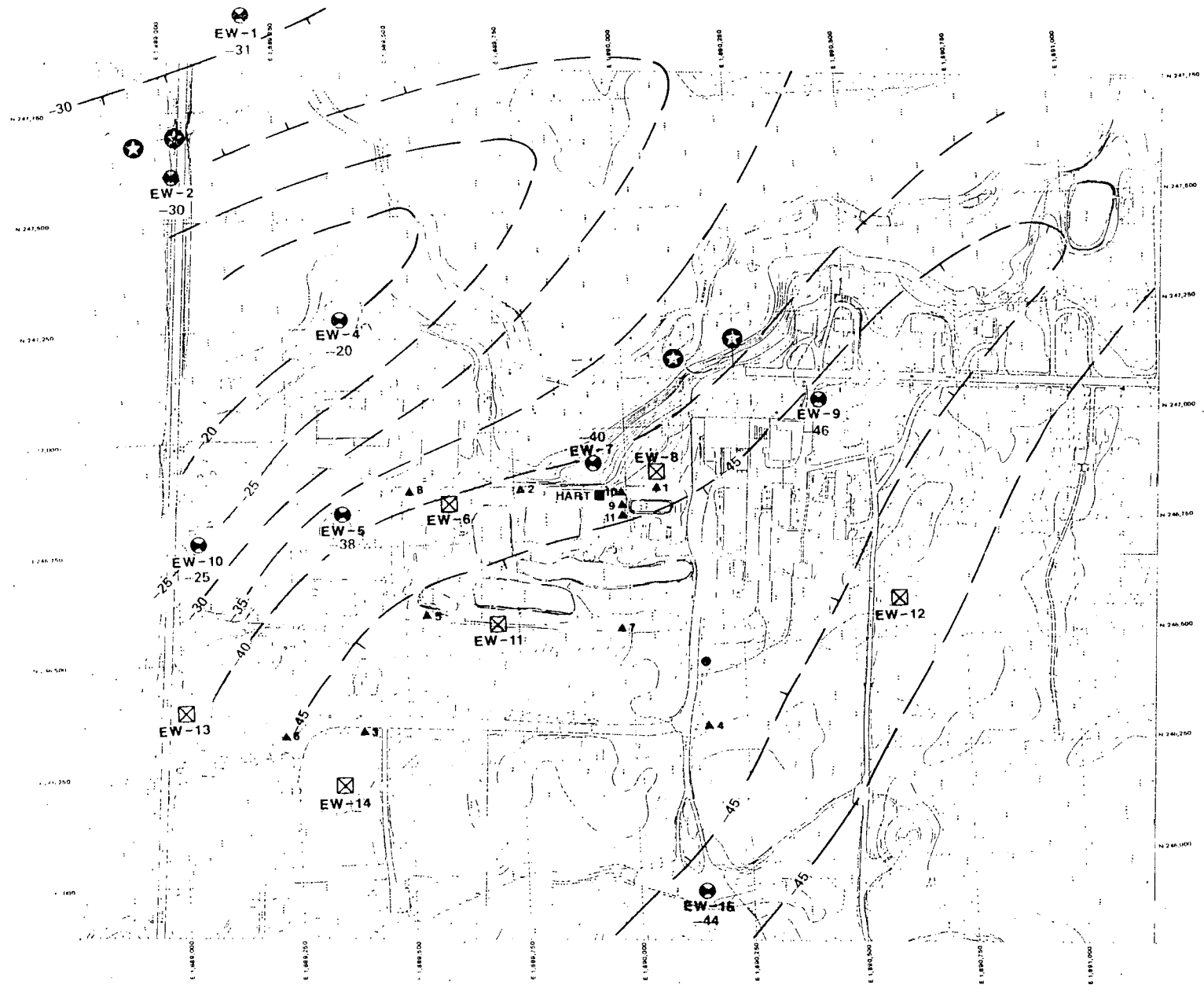
VINELAND CHEMICAL COMPANY SITE

FIGURE 3-7

STRUCTURE CONTOURS AT BASE
OF UPPER SAND

EBASCO SERVICES INCORPORATED

UTW 001 1000



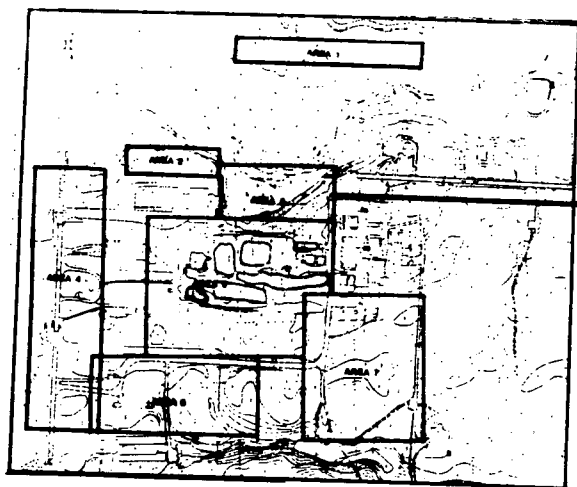
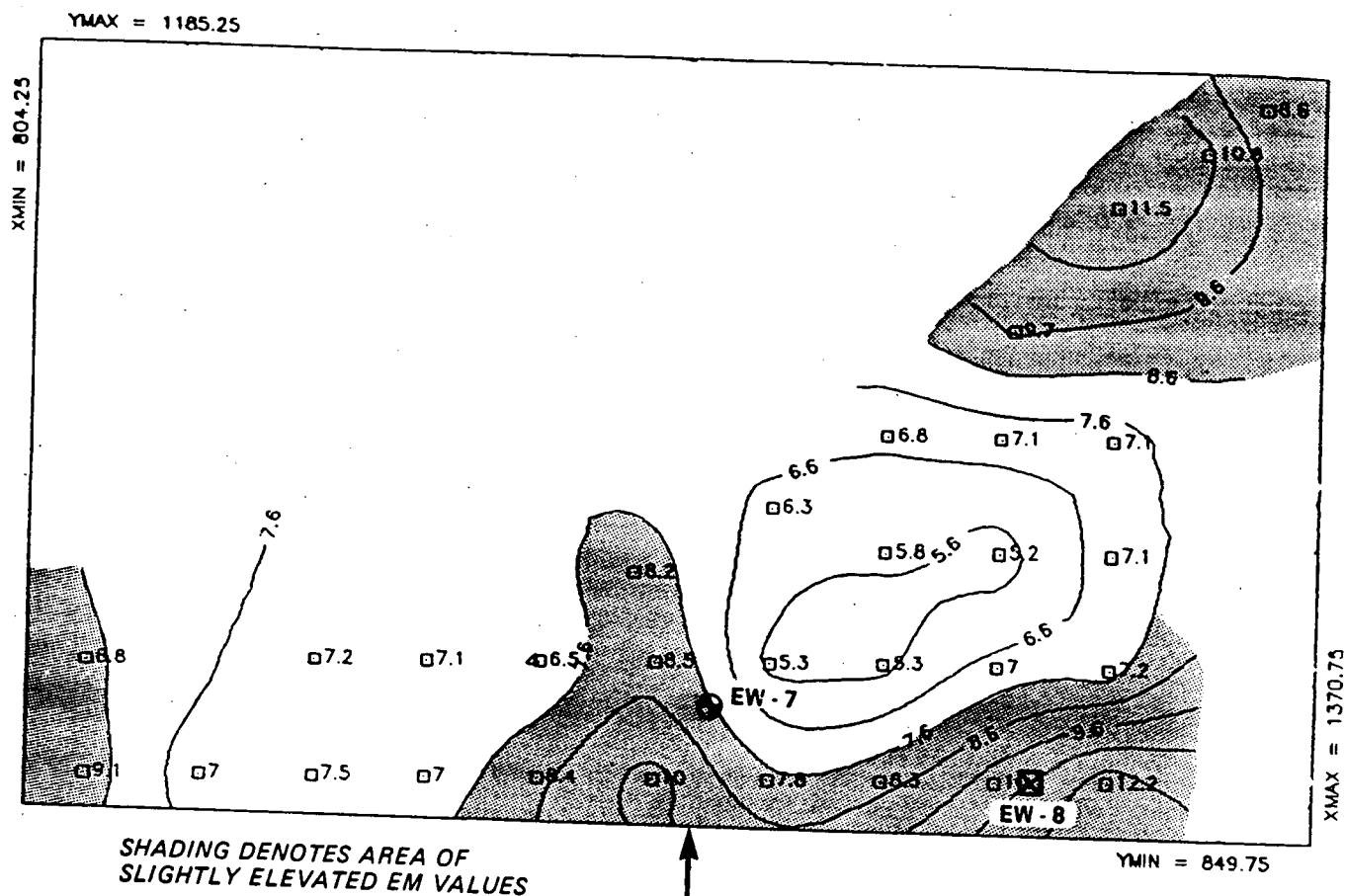
- ⊗ TRIPLE WELL CLUSTER (8)
- ⊠ DOUBLE WELL CLUSTER (6)
- ★ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART (1)

5' CONTOUR INTERVAL
 0 100 200 300
 SCALE IN FEET

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

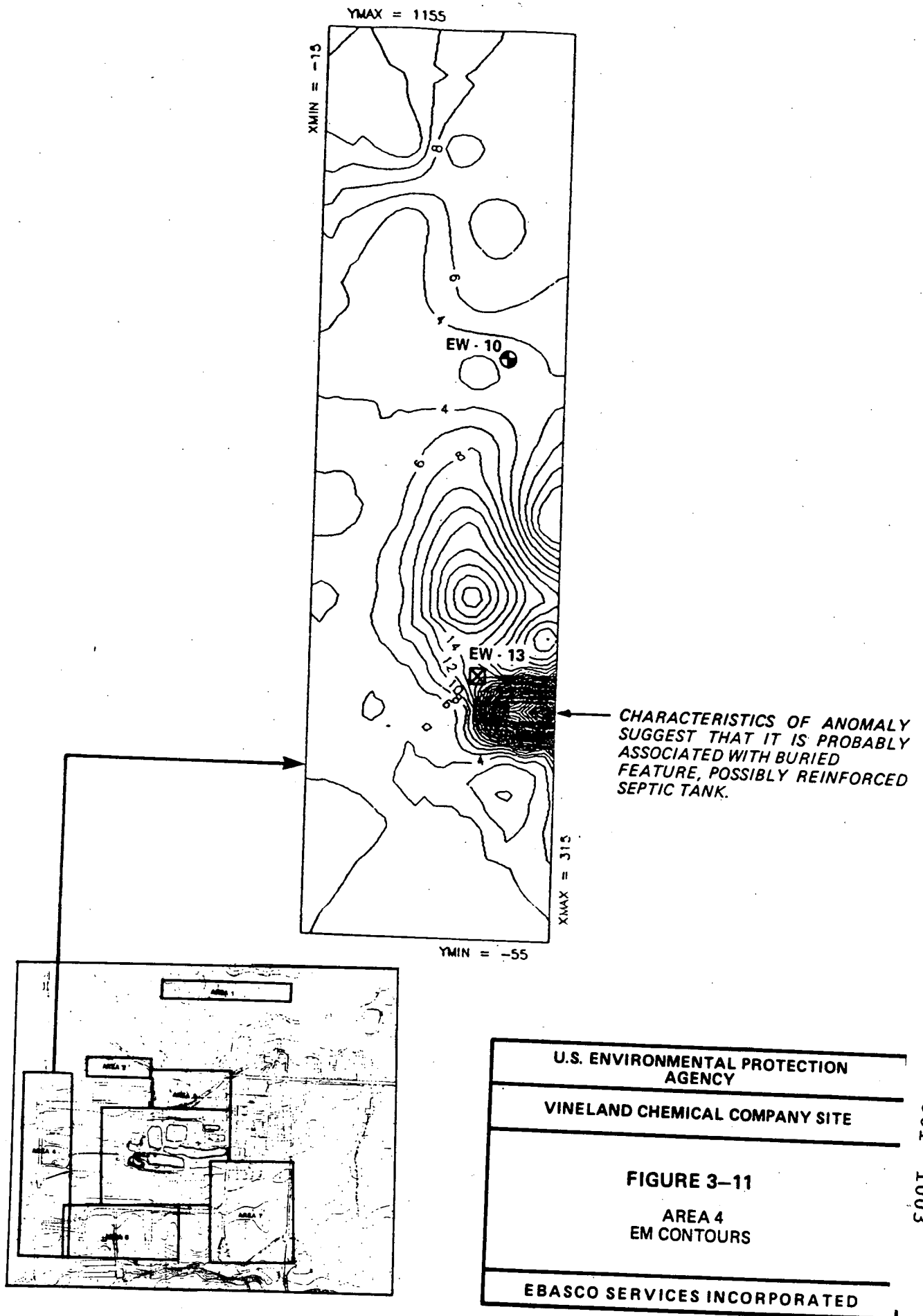
U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-8 STRUCTURE CONTOURS ON TOP OF LOWER SAND
EBASCO SERVICES INCORPORATED

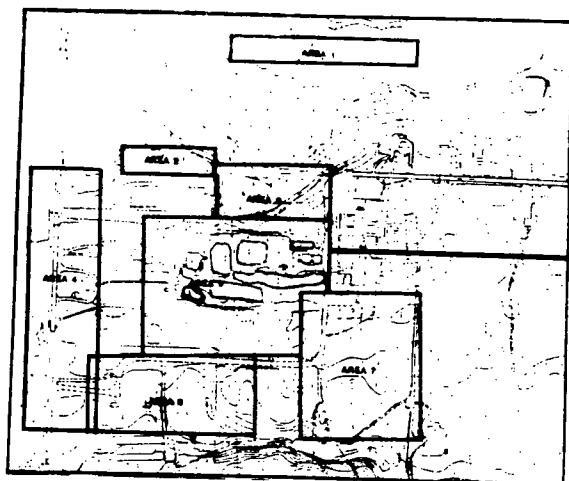
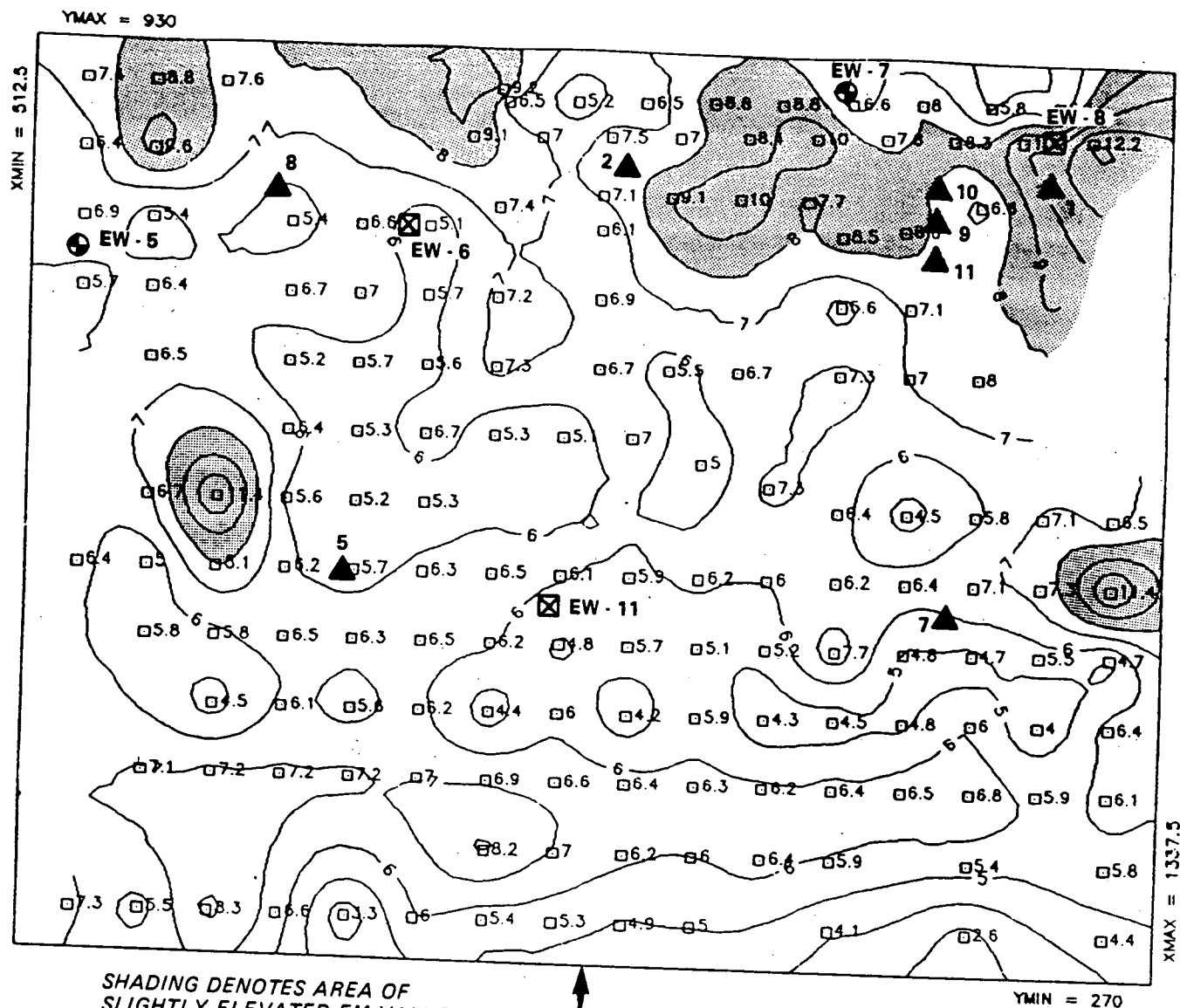
VINELAND CHEMICAL COMPANY



U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-10 AREA 3 EM CONTOURS
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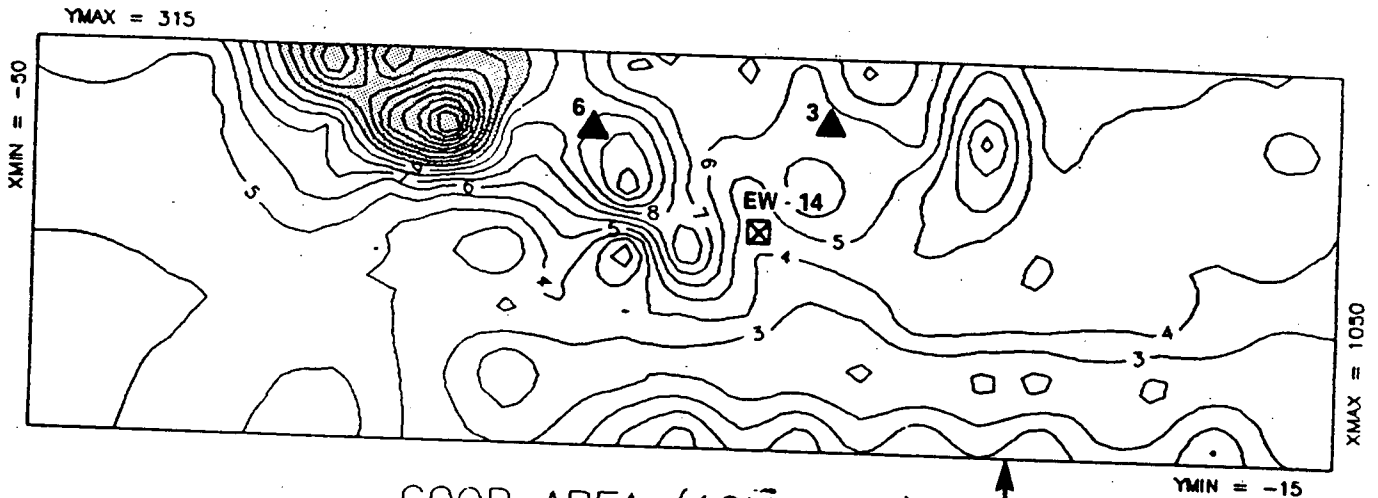
VIN 001 1002



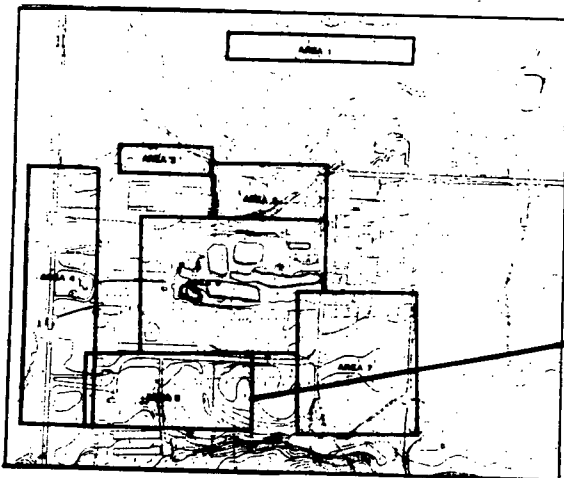


U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-12 AREA 5 EM CONTOURS
EBASCO SERVICES INCORPORATED

VIN 001 1004

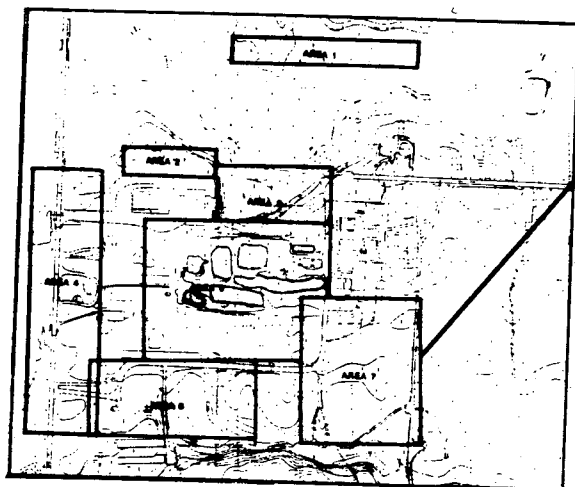
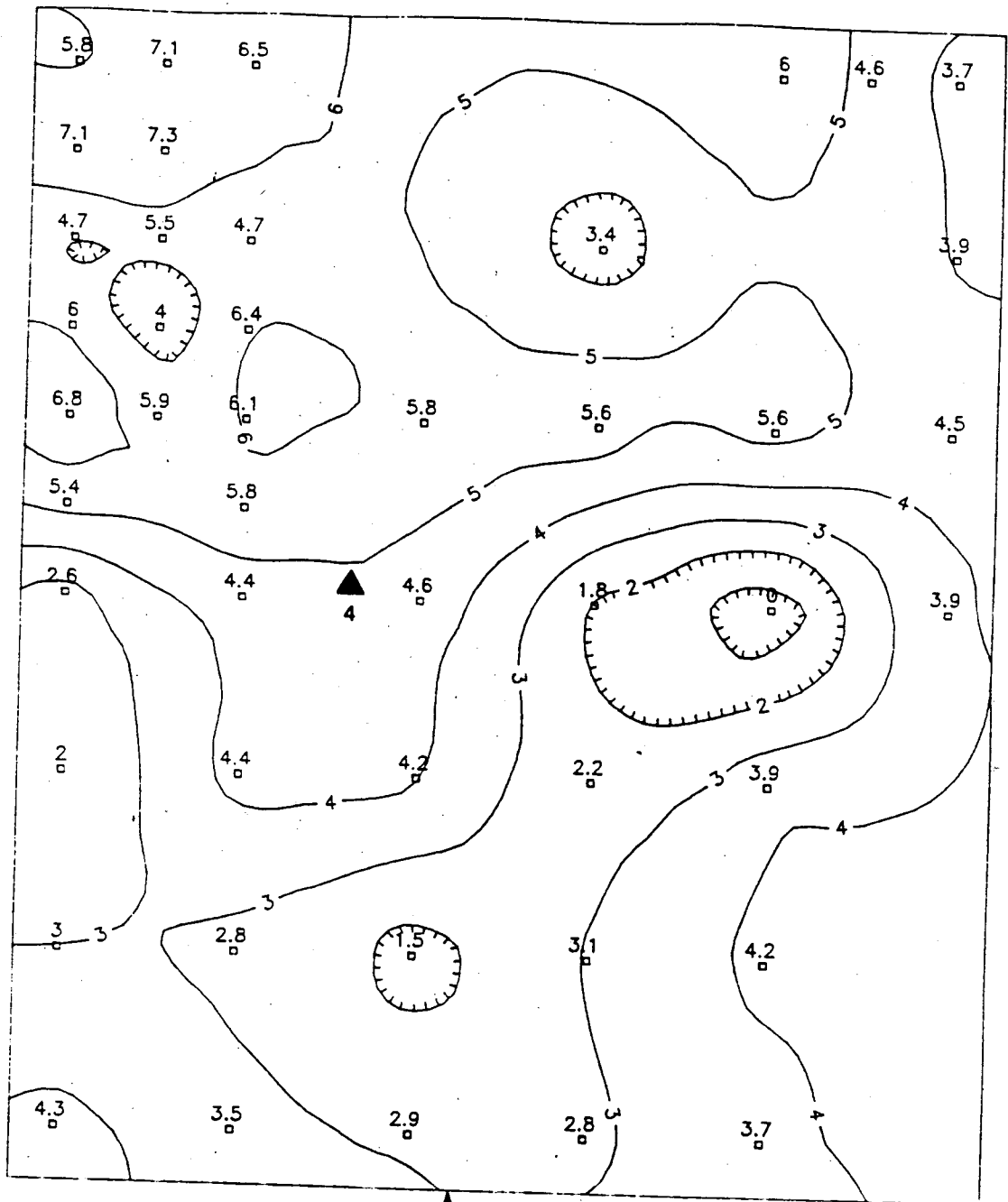


SHADING DENOTES AREA OF
SLIGHTLY ELEVATED EM VALUES



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VINELAND CHEMICAL COMPANY SITE
FIGURE 3-13
AREA 6 EM CONTOURS
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VIN 001 100 5



U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-14 AREA 7 EM CONTOURS
EBASCO SERVICES INCORPORATED

VIN 1001 1006

The background apparent resistivity is very high (approx. 50,000 ohm - feet) near the surface. Such values are typical of very clean (little to no clay fraction) sands. The apparent resistivity drops significantly at a depth of about six feet, probably indicating the depth of the water table. The apparent resistivity at and below the water table is approximately 600 ohm - feet to a depth of about 26 feet. At this depth, a high apparent resistivity layer (8,000 ohm - feet) exists which could reflect a change in lithology.

In contrast, the resistivity sounding curve for Area 3 suggests a much lower apparent resistivity (less than 2000 ohm - feet) near the surface. The apparent resistivity drops to a low of about 400 ohm - feet at a depth of approximately 25 feet. This low resistivity zone, which extends to a depth of about 44 feet, might reflect the presence of electrically conductive contaminants at depth. This sounding was located based on apparently anomalous terrain conductivity readings.

The electrical sounding curve for Area 6 indicates a lower surface apparent resistivity (29,000 ohm - feet) than background (52,000 ohm - feet). This sounding was performed near the location of an old chicken coop used for chemical storage that was suspected to be a point source of contamination. In addition, a thick zone (50 feet) of low apparent resistivity exists below the site starting at a depth of approximately three feet. This zone is more than twice the thickness of the zone of low apparent resistivity observed in the background sounding.

Metallic debris was detected at several of the planned drilling sites. For these sites, the precise location for drilling was shifted slightly, to where no metal was detected. Sites which showed no change from the observed background terrain conductivity were considered free of buried metallic drums or other similarly large metallic objects.

The geophysical data were evaluated in light of information about the site hydrology, groundwater quality, and boring logs to delineate the cause of the geophysical anomalies. Specifically, apparent terrain conductivity (EM) data were compared to the following: 1) specific conductivity; 2) dissolved arsenic, aluminum, and iron content within the groundwater; 3) boring logs; and 4) depth of water table.

Data from the shallow wells best represent the groundwater conditions at the depth targeted by the geophysical survey (approximately 13 feet, the depth which had the greatest influence upon the total observed instrument response). Water quality data from the intermediate and deep wells could not be

VIN 001 1007

compared to the terrain conductivity data because sample depth exceeded the sensing limits of the coil configuration used in the EM survey. The shallow well data and terrain conductivity data is discussed below.

SPECIFIC CONDUCTIVITY VS. METALS CONCENTRATION

The specific conductivity of groundwater is proportional to the concentration of ions in solution. The extent of influence the specific conductivity of groundwater has upon terrain conductivity depends largely upon how conductive the groundwater is compared to the other parameters which also influence terrain conductivity. If the specific conductivity of the groundwater is significant enough to impact the terrain conductivity, this could be used as an indicator of relative ionic concentration within the groundwater.

The specific conductivity of all wells was plotted versus the ionic concentrations of aluminum, iron, and arsenic in Figures 3-15 through 3-17 to determine if any of these metals occurred in concentrations significant enough to control the specific conductivity. If a relationship was observed, then it might have been possible to associate terrain conductivity with the concentrations of a given metal (i.e., arsenic) across the site. Analysis of the plots, however, suggests that no such correlation to specific conductivity existed for aluminum or iron and suggests only a slight relationship with arsenic.

TERRAIN CONDUCTIVITY VS. SPECIFIC CONDUCTIVITY

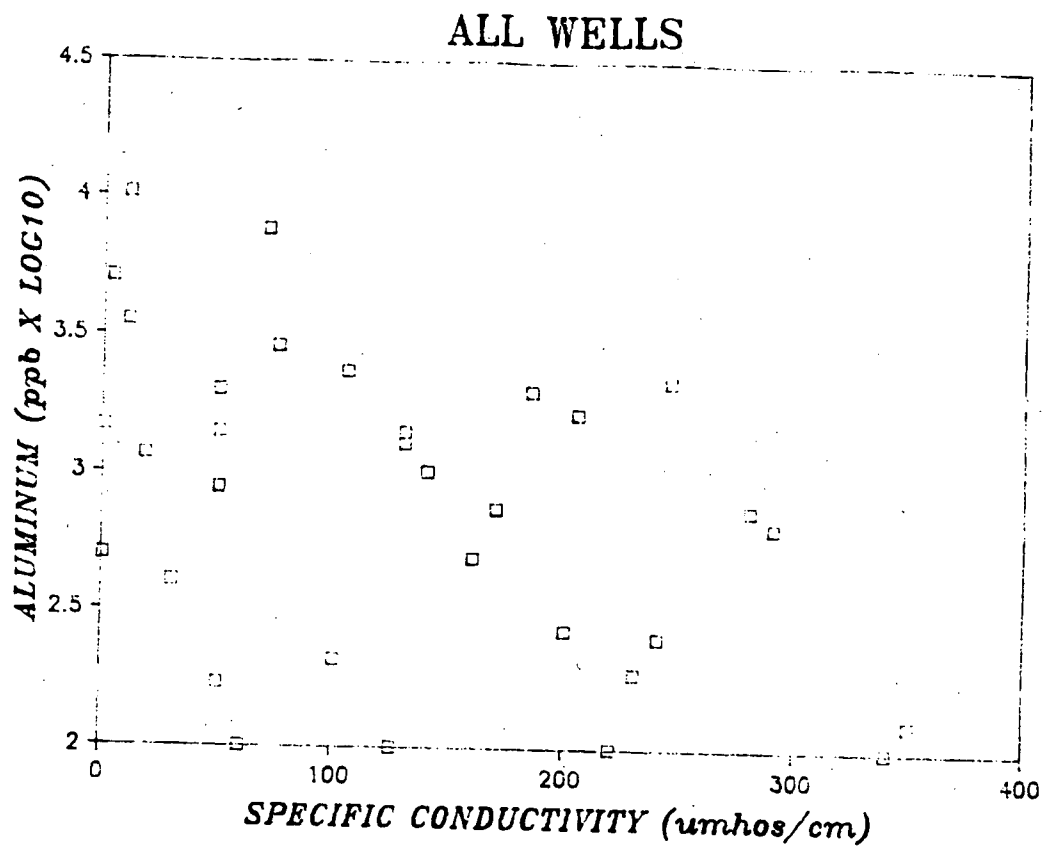
Figure 3-18 is a plot of the terrain conductivity at each of the shallow wells versus the corresponding specific conductivity. There is no apparent relationship between these two parameters. The plot probably indicates that the specific conductivity of the groundwater is too low to have a significant impact on the terrain conductivity.

TERRAIN CONDUCTIVITY VS. METALS CONCENTRATION

Terrain conductivity was plotted versus aluminum, iron, and arsenic ion concentrations for the shallow wells in Figures 3-19 through 3-21. There appears to be no correlation between terrain conductivity and either the aluminum or iron concentrations. However, a slight relationship may exist between terrain conductivity and arsenic ion concentrations.

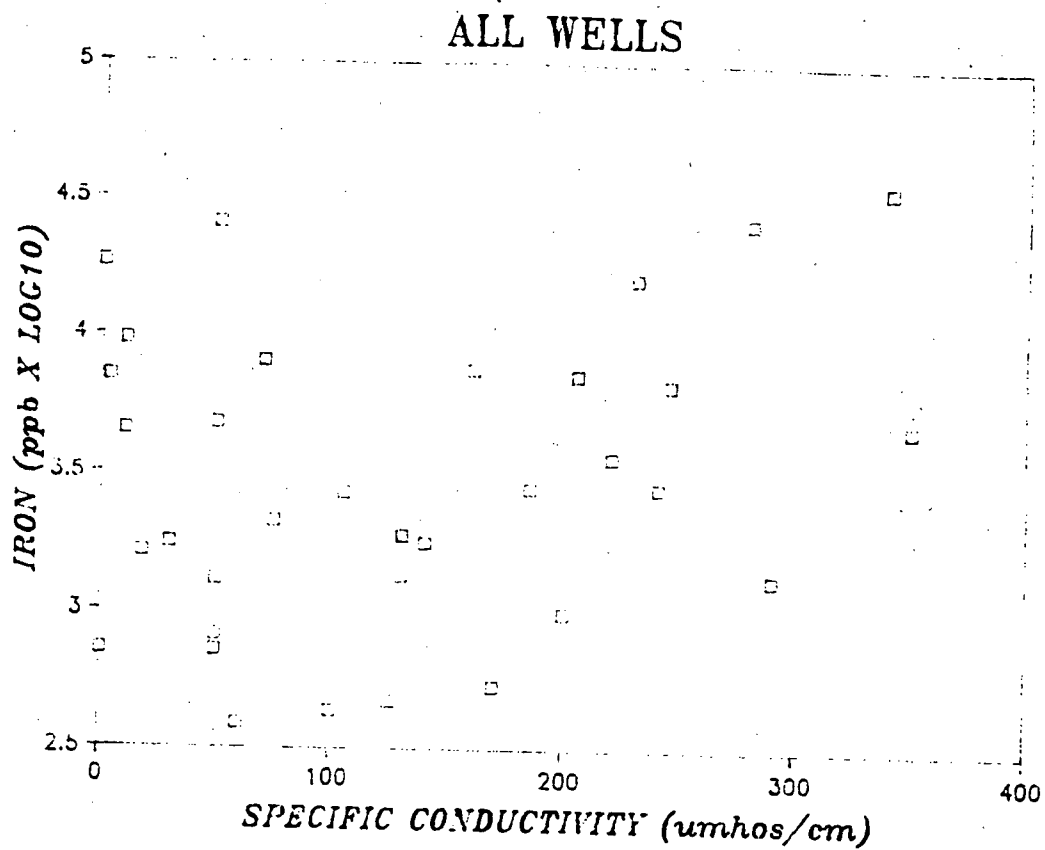
TERRAIN CONDUCTIVITY VS. HYDROGEOLOGY

Terrain conductivity was compared to the boring logs for all of the monitoring wells within the geophysical grids. Only the

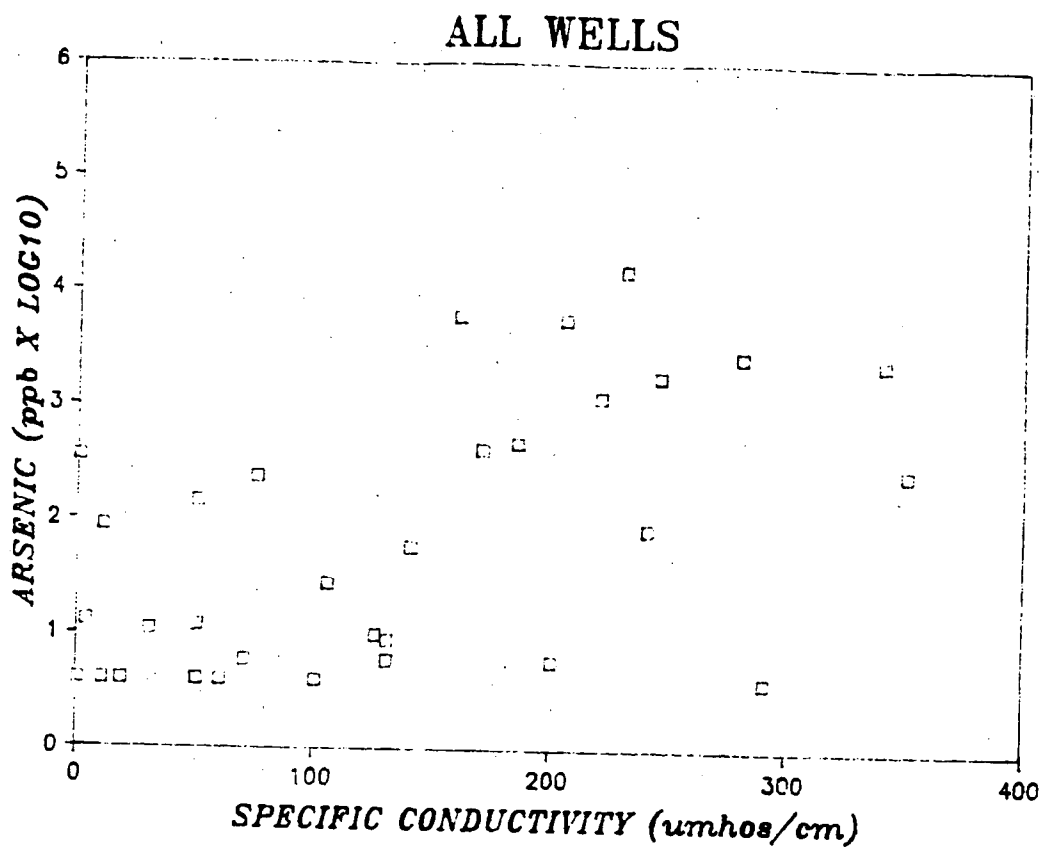


U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-15 SPECIFIC CONDUCTIVITY VERSUS ALUMINUM
EBASCO SERVICES INCORPORATED

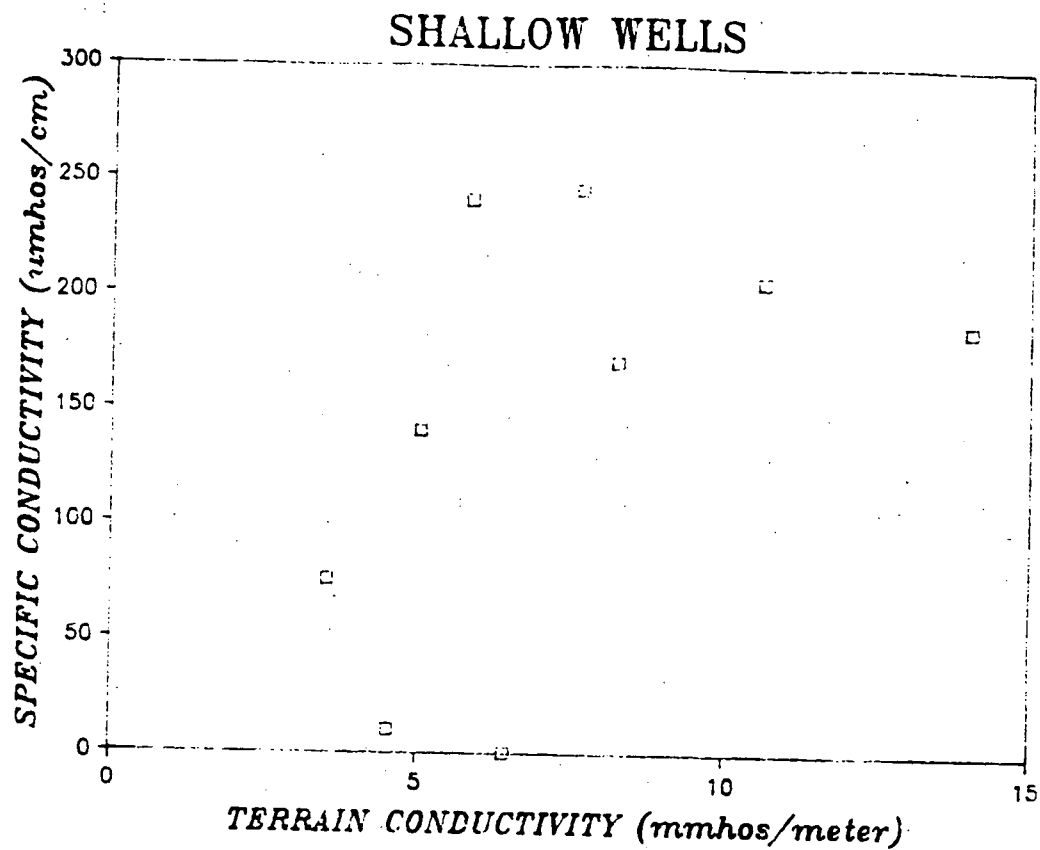
VIN 101 1009



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VINELAND CHEMICAL COMPANY SITE
FIGURE 3-16 SPECIFIC CONDUCTIVITY VERSUS IRON
EBASCO SERVICES INCORPORATED



U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-17 SPECIFIC CONDUCTIVITY VERSUS ARSENIC CONCENTRATION
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U.S. ENVIRONMENTAL PROTECTION
AGENCY

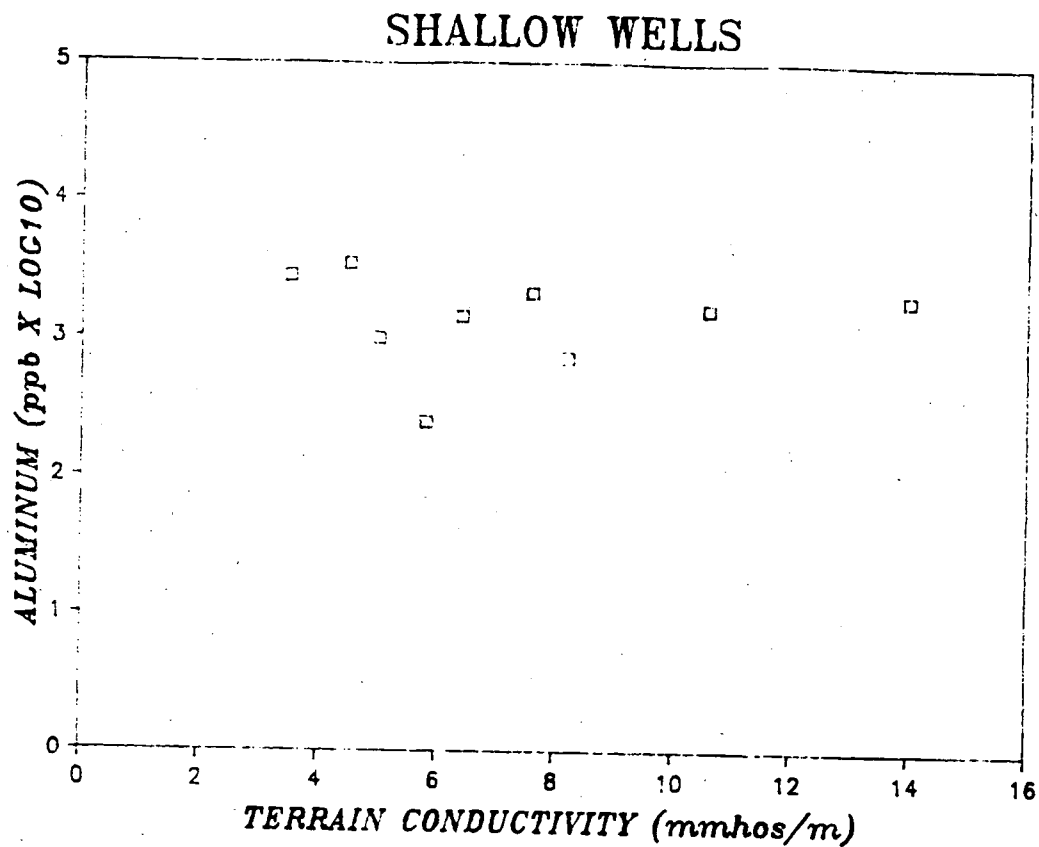
VINELAND CHEMICAL COMPANY SITE

FIGURE 3-18

TERRAIN CONDUCTIVITY
VERSUS SPECIFIC CONDUCTIVITY

EBASCO SERVICES INCORPORATED

VIN 001 1012



U.S. ENVIRONMENTAL PROTECTION
AGENCY

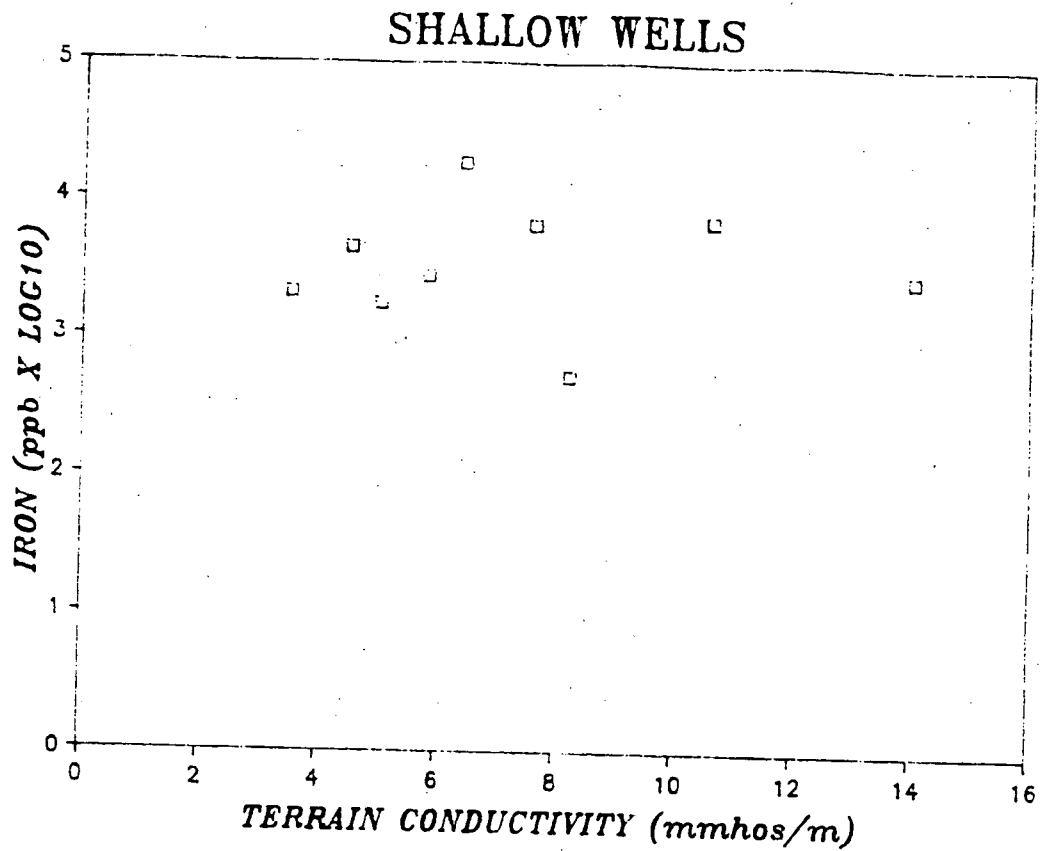
VINELAND CHEMICAL COMPANY SITE

FIGURE 3-19

TERRAIN CONDUCTIVITY
VERSUS ALUMINUM CONCENTRATION

EBASCO SERVICES INCORPORATED

VIN 001 1013



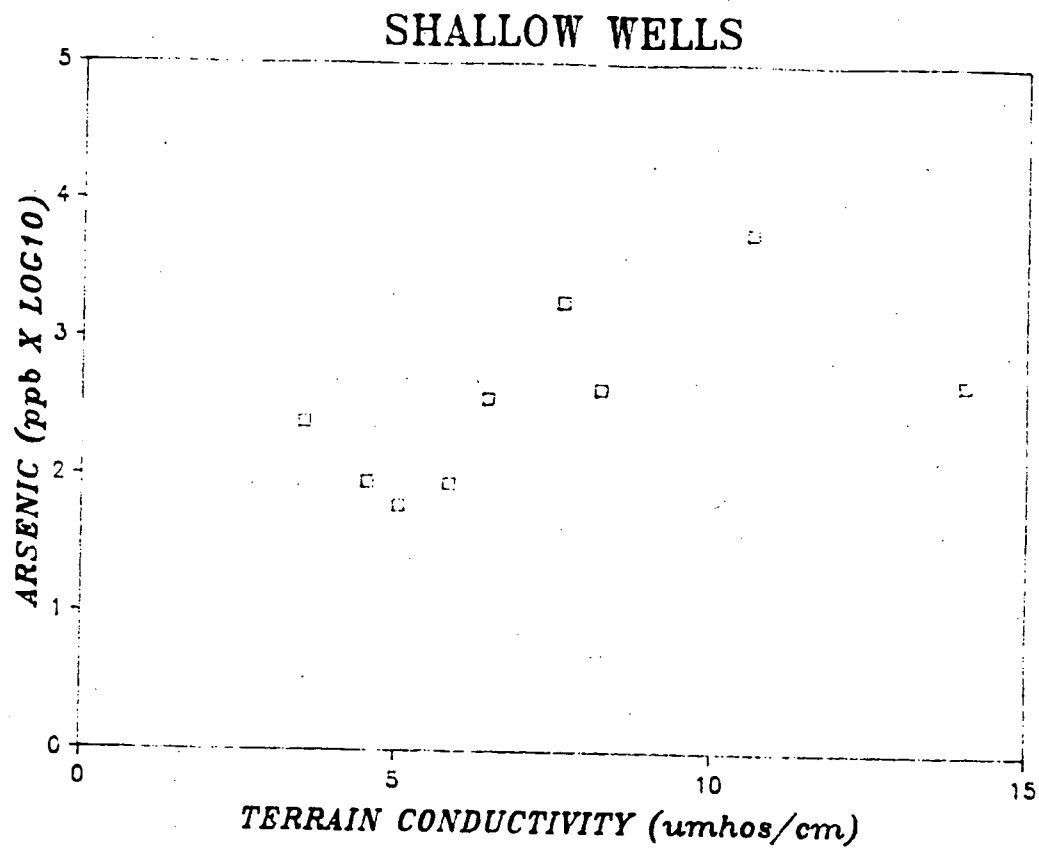
U.S. ENVIRONMENTAL PROTECTION
AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 3-20

TERRAIN CONDUCTIVITY
VERSUS IRON CONCENTRATION

EBASCO SERVICES INCORPORATED



U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-21 TERRAIN CONDUCTIVITY VERSUS ARSENIC CONCENTRATION
EBASCO SERVICES INCORPORATED

upper 30 feet was considered. Review of the logs showed no significant variation in grain size to account for the observed range in terrain conductivity. The borings logs indicate that fine to medium sands underlie the entire site.

Terrain conductivity was also compared to water table depth as shown in Figure 3-22. There is no clear relationship between the terrain conductivity and the depth to water. The inability of the groundwater to significantly impact the terrain conductivity can be attributed to the groundwater having a low specific conductivity.

3.2.2 Survey Conclusions

The geophysical data show no significant geophysical anomalies. There appears to be no significant relationship between the terrain conductivity and groundwater quality, lithology, or depth to water table. The specific conductivity of the groundwater is not high enough to produce a noticeable effect on the terrain conductivity across the site. Consequently, most of the observed terrain conductivity values appear to be within the range of background variations.

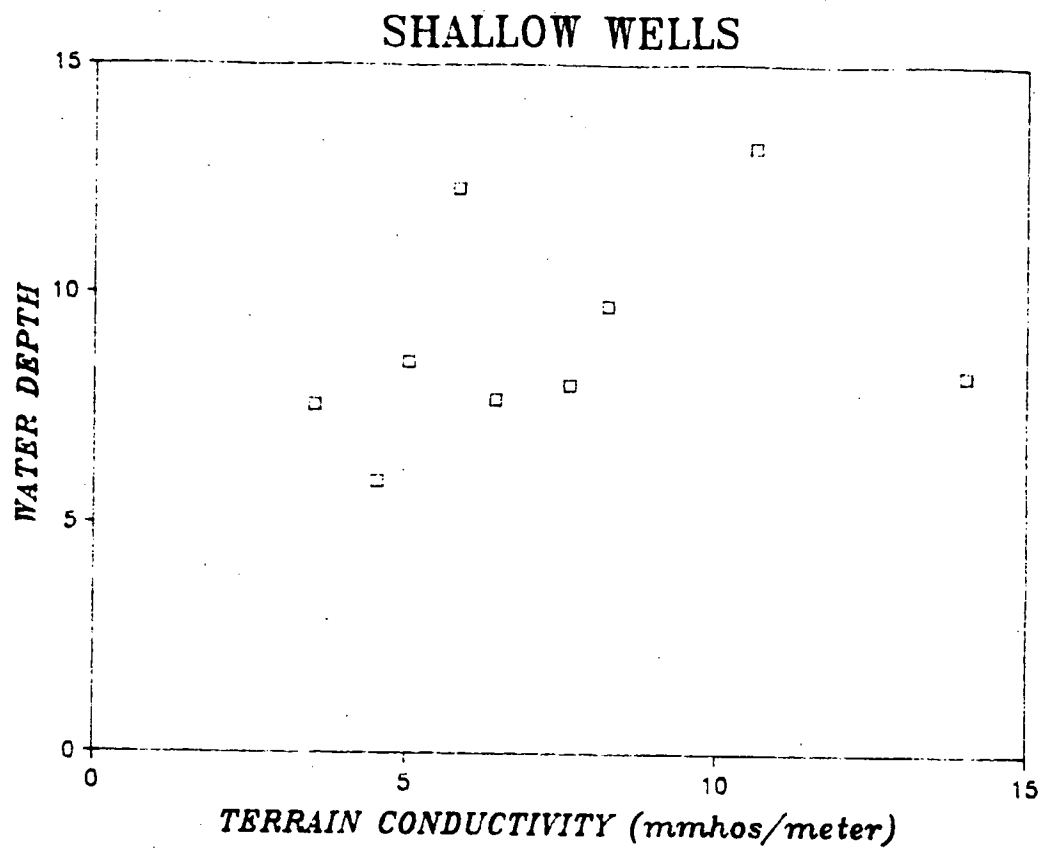
The cause of the slightly elevated terrain conductivity values north of the active lagoons (Figures 3-10 and 3-12) is unknown. The possibility exists that contamination may be the source of the elevated values; however, cultural interference may also be the cause.

The EM survey coil spacing mandated by the relatively high levels of cultural background noise restricted the effective sensing depth to generally less than 25 feet. Consequently, the results of the EM survey do not preclude the presence of a deeper contaminant plume as suggested by elevated specific conductivity (2,200 umhos/cm) and arsenic (361,000 ug/l) detected in groundwater from monitoring well EW-4M. Although use of a greater coil spacing for EM surveying would sense to depths where significant contamination is observed, logistical complications at the site (proximity to cultural features and terrain obstacles) makes such a survey impractical.

3.3 SOIL INVESTIGATION

3.3.1 Physical Characteristics

Grain size analyses were performed on soil samples taken at the Ebasco well screen settings and on sediments from the bottom of the unlined lagoon, UL-A. Permeability and Atterberg limit analyses were performed on the dark grey material seen at the top of the lower sand at depths of 115 feet to 127 feet in monitoring well borings EW-4, EW-7, EW-9 and EW-15. The grain size, permeability, and Atterberg limit analyses are presented in Section III of Appendix A.



U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-22 TERRAIN CONDUCTIVITY VERSUS WATER DEPTH
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The grain size analyses were classified in phi (ϕ) units, which are proportional to the variety of grain sizes found in a particular sample. The phi units correspond to grains sizes larger than sand, (less than 1), sand (-1 to 4), silt (4 to 8), and clay (greater than 8).

The visual geologic descriptions of the soil samples match the grain size analyses for the samples very well. Most of the subsurface samples contained 85%-99% sand and most contained between 0% and 10% silt or clay. Very few samples contained particles larger than sand. The majority of the grain size analyses reflect the occurrence of medium sand throughout the subsurface with little silt, clay or larger-than-sand particles. At EW10M-34, there is coarse sand and fine gravel which is reflected by the 32.7% larger-than-sand particles. At EW1M-31 it is believed that the sample was taken of wash because 93.5% of the particles were larger-than-sand, which is too high for the observed medium-to-fine sand with coarse sand and gravel. The grain size distributions of all of the samples are fairly uniform with depth.

The grain size analyses of the surface sediments from the unlined lagoon show uniform sand contents with little or no fine or coarse particles. All six samples show very little to no silt, clay or larger-than-sand size particles.

The Soil Survey of Cumberland County (Van R. Powley, USDA Soil Conservation Service, 1973) has identified the surface soils in the vicinity of the ViChem site as being a loamy sand, found on slopes of 0 - 3% grade. Named the Klej Soil Series, it consists of mostly moderately well drained, permeable soils that are subject to blowing when drained during the summer months.

The permeability results of the dark grey material at the top of the lower sand encountered at EW-4D, EW-7D, EW-9D and EW-15D range between 4.5×10^{-9} cm/sec and 6.2×10^{-9} cm/sec. (These tests were done in a triaxial cell using a falling head, per ASTM Method D4318). In the remaining deep borings, there was not enough clay at the top of the lower sand to take a Shelby Tube sample.

The Atterberg limits describe the water content at which soil consistency changes from a solid to a plastic and from a solid to a liquid. The liquid limit is the amount of water at which the soil on two sides of a groove flows together after the soil has been dropped 25 times through a distance of 1 cm. The plastic limit is the amount of water at which the soil crumbles when it is rolled to a thread 1/8 of an inch in diameter (Wu, 1976). The different clay minerals in soils exhibit different consistencies at the same water content.

The liquid limit results of the Shelby Tube samples from EW-4D, EW-7D, EW-9D and EW-15D range between 43% and 58% while the

plastic limit results range between 10% and 25%. When Atterberg limits are plotted on a plasticity chart, the conclusion may be made that these four samples are silty clays with some organic content.

3.4 HYDROGEOLOGIC INVESTIGATION

The site is underlain by the Cohansey-Kirkwood aquifer, the shallowest and most important source of groundwater in Cumberland County (Rooney, 1971). The Cohansey Sand and the upper Kirkwood Formation occur from near land surface to a depth of approximately 180 feet. In this geologic section, the overlaying Cohansey Sand cannot be differentiated from the Kirkwood Formation.

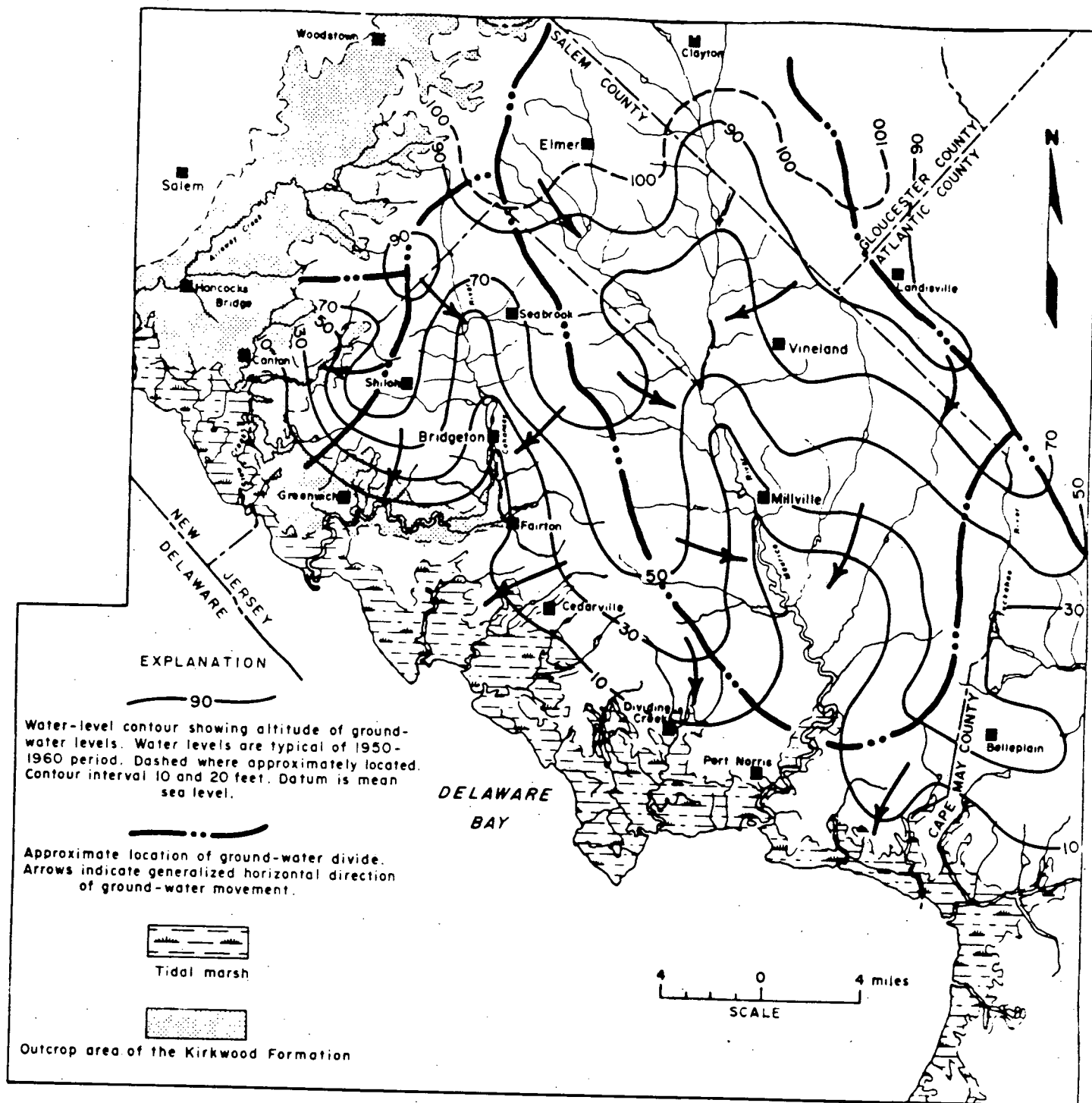
Figure 3-23 indicates the pattern of water movement in the Cohansey-Kirkwood aquifer in Cumberland County from water levels taken during 1950-1960. The arrow north of the City of Vineland in Figure 3-23 indicates that the generalized horizontal groundwater movement in this area is to the west, toward the Maurice River. Lateral and deep percolating groundwater flow is from higher elevations, in the northern part of the county to lower areas along stream valleys and the Delaware Bay.

Physical and chemical data were obtained to characterize the aquifer under the site for this RI. The types of physical data obtained and presented in the following sections include continuous water level records from well clusters EW-4, EW-5, EW-7 and EW-15, 15 rounds of water levels taken between June, 1987 and March, 1988, the analyses of a pumping test that was performed by Ebasco on MW-10 on July 28, 1987, and single well tests performed during groundwater sampling. The chemical data is discussed in Section 4.0

3.4.1 Aquifer Characteristics

The gamma-ray logs that were performed on the Ebasco well borings indicated the occurrence of a continuous banded zone separating the upper sand from the middle sand between 38 feet and 77 feet below the surface. The shallow and intermediate wells were set at the top and base of the upper sand, respectively. The deep wells were set at the base of the middle sand, on top of the lower sand, except for EW-5D. This well is screened in the lower sand, as is the ViChem production well and the Hart well. The monitoring well locations were presented in Figure 2-4, while the depths of the monitoring wells were presented in Table 2-4.

The hydrogeological investigation was designed to characterize the aquifer down to the top of the lower sand. The top of the lower sand is characterized by a grey silty sand or clay. This is the known marker below which production wells in the area are believed to be drawing water. The hydrogeological investigation was designed not to penetrate to this depth until chemical analysis confirmed the existence of contamination above it.



MAP PREPARED BY: J. G. ROONEY, GROUNDWATER RESOURCES, CUMBERLAND COUNTY, N.J. USGS, WATER RESOURCES DIVISION, 1971.

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-23
GENERALIZED WATER LEVELS IN THE COHANSEY-KIRKWOOD AQUIFER
EBASCO SERVICES INCORPORATED

VIN 001 1020

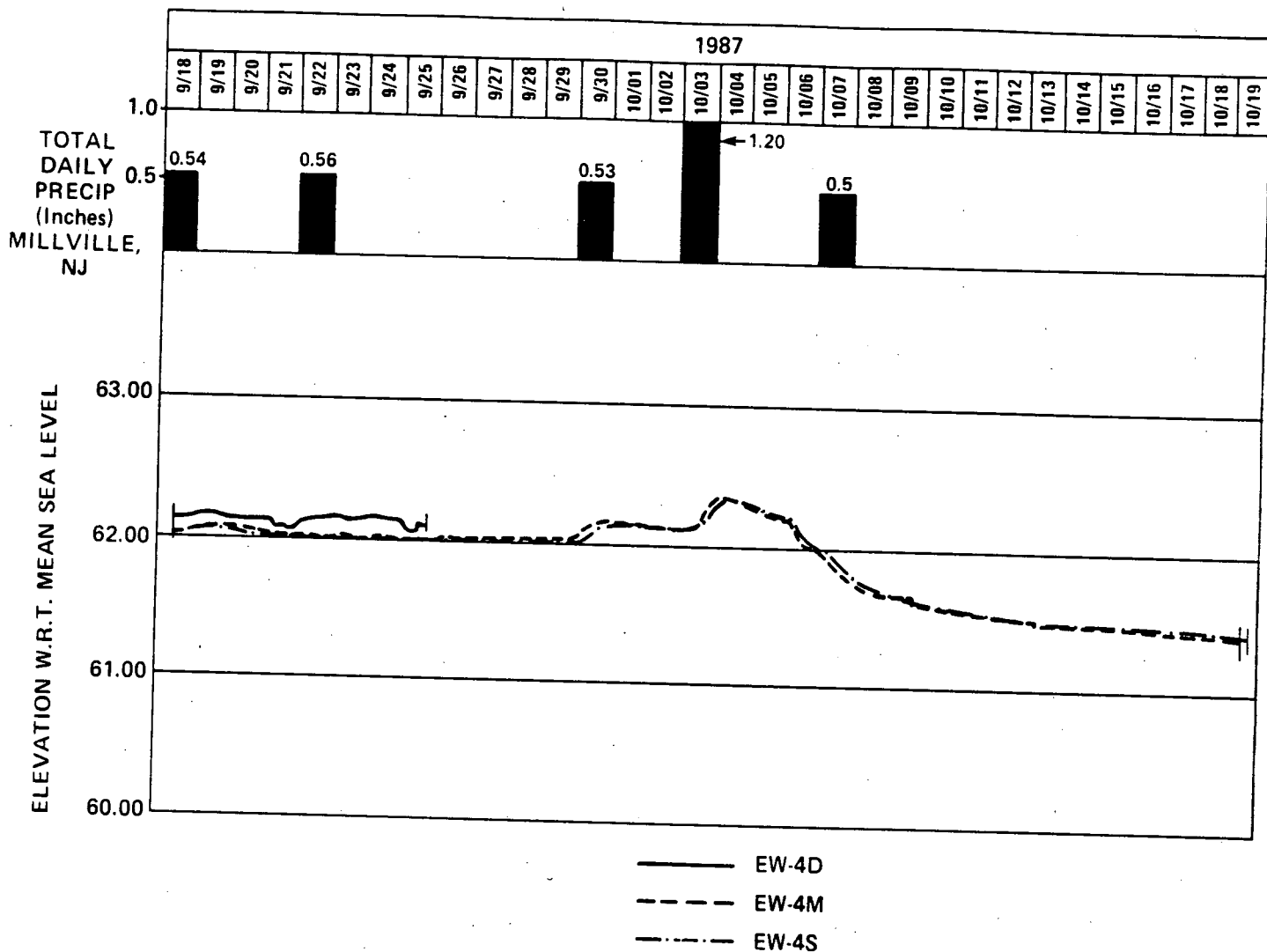
3.4.1.1 Water Level Records

Figures 3-24, 3-25, 3-26 and 3-27, show the continuous water level records for well clusters EW-4, EW-5, EW-7 and EW-15. These figures reflect the water level fluctuations for the different wells in each of the four clusters. For EW-4, EW-5 and EW-15 there are traces from the shallow, medium and deep wells while Figure 3-26 shows the traces for the deep and medium wells in the EW-7 cluster.

Two different time scales were used in the investigation. The weekly scale was used when Ebasco personnel were on site during the field investigation. The monthly scale was used when personnel were not on site.

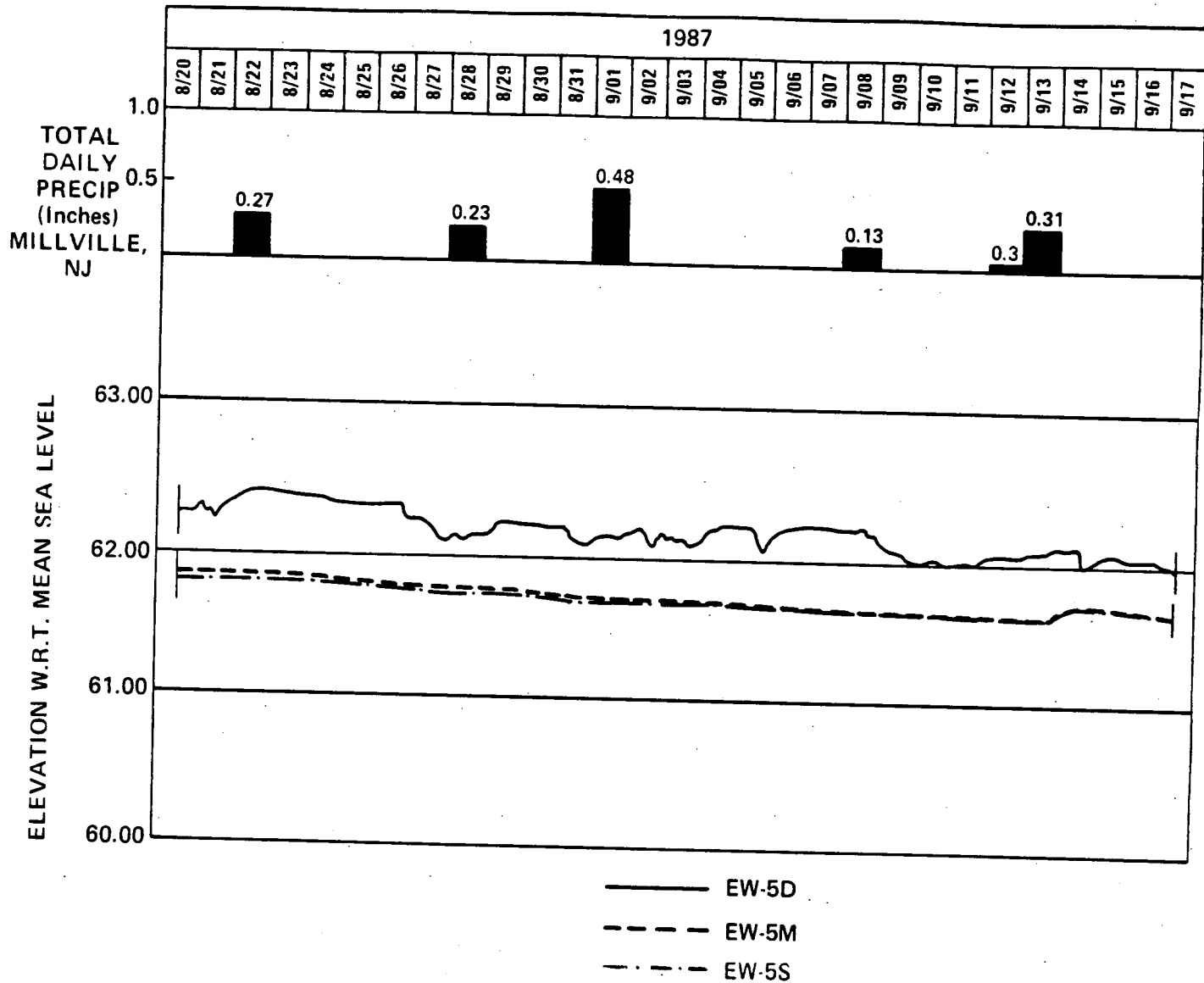
Total daily rainfall was also plotted in Figures 3-24 through 3-27. During the monitoring well investigation, a daily rainfall record was maintained using a rainfall gauge. The daily rainfall record was maintained from May, 1987 through August, 1987. This rainfall record is plotted with the water levels from EW-15. The total daily precipitation for the traces recorded between August and November was obtained from the rainfall station at the Millville FAA Airport (Monthly Climatological Summary NCDC, NOAA, Asheville, North Carolina). The rainfall station results agreed with the rainfall gauge results when the two records overlapped.

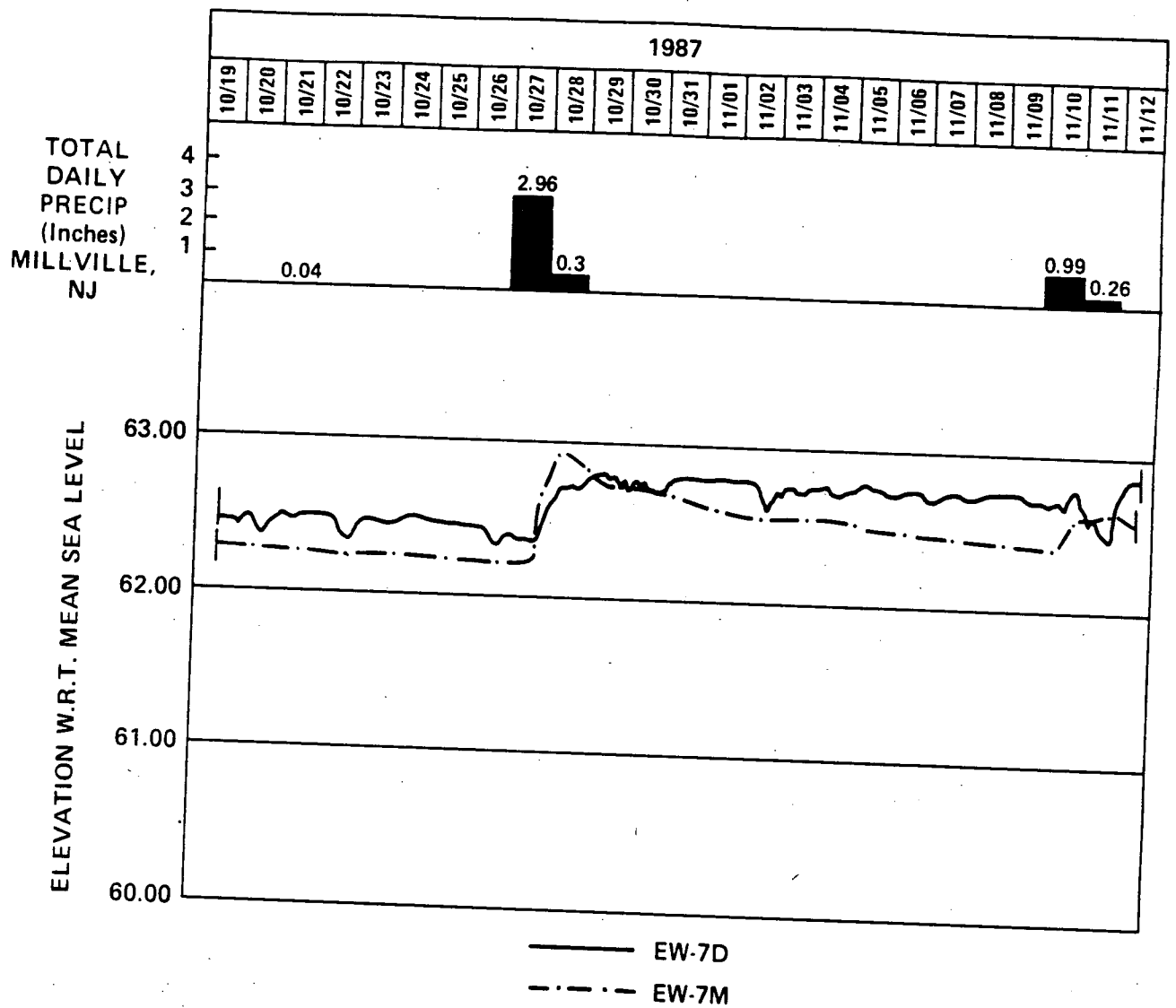
A number of conclusions can be drawn from these hydrographs. On all of the sets, the results show that the shallow and medium wells, both screened in the upper sand, behave identically through time and have virtually identical water levels. The deep wells showed fluctuations, some of which may result from pumping. Between 8/10 and 8/20/87, the trace EW-15D shows the apparent effects of a pump being turned on and off a number of times. The fluctuations in the deep wells' water levels are not seen in the shallow and medium wells. The EW-4, EW-5 and EW-7 hydrographs show the deep wells' water levels being higher in elevation than the shallow wells' water levels. The EW-15 hydrograph shows the opposite trend. A possible explanation for this is that EW-15 is closest to ViChem's pumping well, which is creating a falsely low deep water level. Another possible explanation is that EW-15 is the farthest of these clusters from the Blackwater Branch. The EW-7 hydrograph shows both the deep and shallow water levels reacting to rainfall after 10/27/87 with the shallow trace reacting so much that it rose above the deep trace before lowering back to equilibrium. The deep trace may have risen due to overlaying pressures.



U.S. ENVIRONMENTAL PROTECTION AGENCY	
VINELAND CHEMICAL COMPANY SITE	
FIGURE 3-24	
HYDROGRAPH: 9/18 - 10/19 EW-4 CLUSTER	
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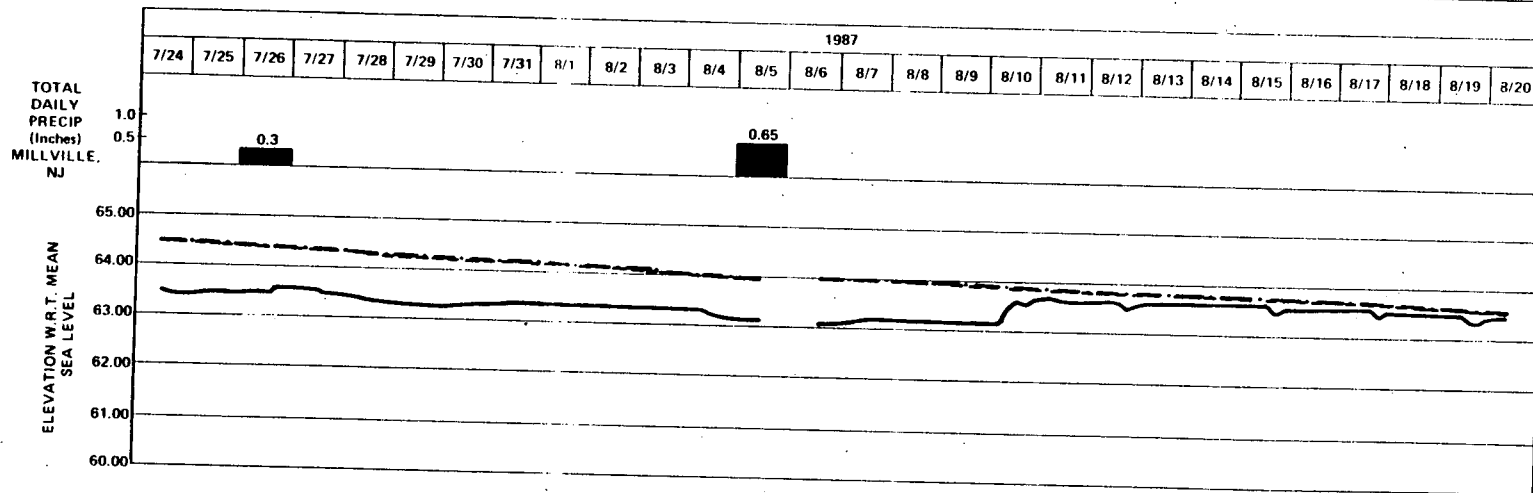
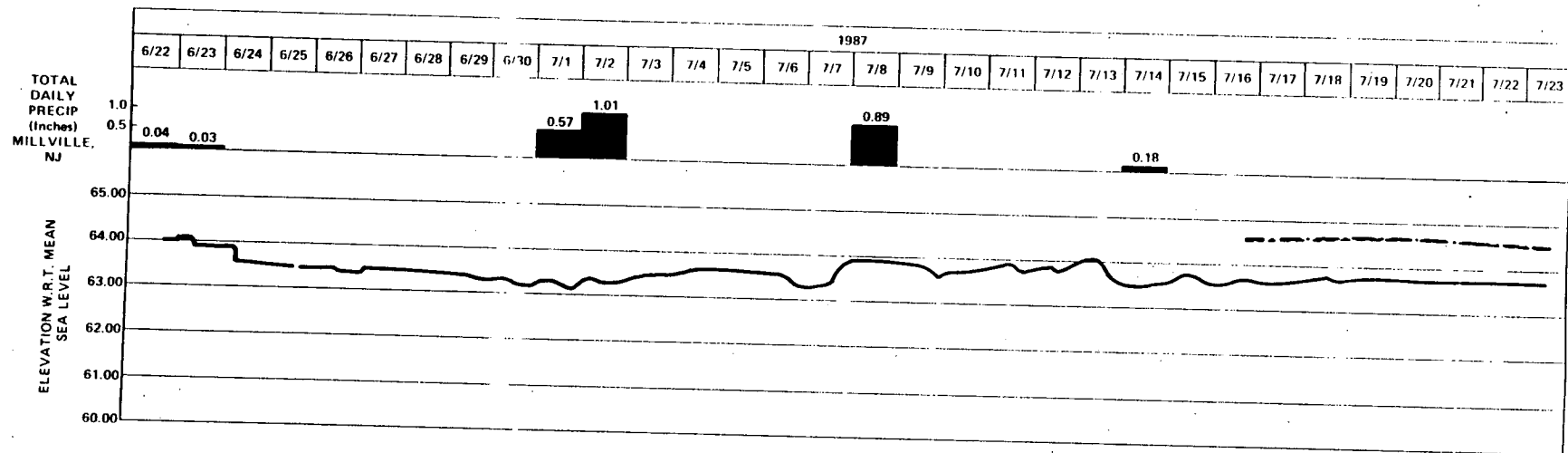
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U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
<p>FIGURE 3-26</p> <p>HYDROGRAPH: 10/19 - 11/12 EW-7 CLUSTER</p>
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VIN 001 1024



— EW-15D
 --- EW-15M
 -.- EW-15S

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-27
HYDROGRAPH 6/22-8/20 EW 15 CLUSTER
FRASCO SERVICES INCORPORATED

5201 100 NIA

Table 3-3 presents the 15 rounds of water level measurements made on all of the monitoring wells. These measurements included stream gauge water level measurements at two locations on the Blackwater Branch; where the branch crosses beneath Mill Road and farther upstream near Building #9. Two stream gauges are shown on the site map at both the upstream and downstream locations. The second gauges were installed before the beaver dam at Mill Road was destroyed. The second gauges were placed towards the center of the stream to accommodate the lowering of the stream's level. The water levels in the monitoring wells were obtained with stainless steel tapes and chalk or with calibrated electric sounding devices (m-scopes).

Just as the Stevens water level traces indicated, Table 3-3 shows that the water levels in the shallow and medium wells in the same cluster were virtually identical. In addition, the water levels of the deep wells were all slightly higher in elevation than their associated shallow and medium wells.

The continuous water level traces, the rounds of water levels and the geologic interpretation of the gamma-ray logs, indicate that the banded zone is a less permeable layer than the upper sand and acts as a low permeability zone separating the upper and middle sands. The chemical results, which are discussed in Sections 4 and 5, show that there is extensive groundwater contamination above the banded zone, but very little below it. In effect, there are two aquifers, the upper sand and the middle sand, separated by the banded zone.

The upper sand is very homogenous. No vertical variations were seen in the water levels of the shallow and medium wells in the same clusters. Also the boring logs and the gamma-ray logs showed a very uniform geology down to the top of the banded zone.

The middle sand is less homogenous than the upper sand. The gamma-ray logs showed clay laminae within the middle sand. The middle sand displayed generally higher water levels than the upper sand.

Below the middle sand is the unit that is pumped by the ViChem production well and the municipal production wells in the area. The separation between the two units is noted by a dark grey marker bed, which consists of sand that contains some very low permeability clays as shown in the permeability results presented previously. The separation between the middle sand and the material below was not fully investigated in this program.

TABLE 3-3

VINELAND CHEMICAL COMPANY WATER LEVEL MEASUREMENTS

TOC ELEV	EW-10		EW-1M		EW-1S		EW-2D		EW-2M		EW-2S		EW-4D	
GRD ELEV	72.89		72.62		73.27		65.63		65.53		65.66		74.86	
NORTHING	247,964.52		247,959.34		247,953.79		247,605.43		247,559.68		247,600.90		247,265.14	
EASTING	1,889,201.52		1,889,199.13		1,889,196.90		1,889,014.59		1,889,012.74		1,889,019.54		1,889,379.31	
	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV
06/16/87														
06/17/87	10.80	62.09												
06/26/87														
06/30/87	10.13	62.76	10.36	62.26			3.48	62.15					12.37	62.49
07/06/87	10.08	62.81	10.11	62.51	10.75	62.52	3.40	62.23					12.46	62.40
07/17/87	9.82	63.07	9.87	62.75	10.43	62.84	3.12	62.51	4.01	61.52			12.39	62.47
07/28/87	10.21	62.68	10.30	62.32	10.97	62.30	3.52	62.11	3.60	61.93	3.69	61.97	12.16	62.70
07/29/87									3.76	61.77	4.22	61.44	12.52	62.34
08/13/87	10.38	62.51	10.50	62.12	11.16	62.11	3.59	62.04	4.51	61.02	4.48	61.18	12.44	62.42
08/20/87	10.50	62.39	10.59	62.03	11.26	62.01	3.74	61.89	4.33	61.20	4.42	61.24	12.65	62.21
09/14/87	10.67	62.22	10.56	62.06	11.22	62.05	3.90	61.73	4.22	61.31	4.31	61.35	12.79	62.07
09/30/87	10.65	62.24	10.45	62.17	11.09	62.18	4.33	61.30	4.76	60.77	4.70	60.96	12.72	62.14
10/19/87	11.02	61.87	11.11	61.51	11.79	61.48	4.64	60.99	5.10	60.43	5.17	60.49	13.10	61.76
11/02/87	10.73	62.16	10.84	61.78	11.51	61.76	3.94	61.69	4.37	61.16	4.50	61.16	12.10	62.76
11/12/87	10.71	62.18	10.84	61.78	11.51	61.76	3.89	61.74	3.37	62.16	3.48	62.18	13.19	61.67
01/27/88	10.39	62.50	10.59	62.03	11.26	62.01	3.64	61.99	4.31	61.22	4.38	61.28	12.66	62.20
03/17/88	10.25	62.64	10.57	62.05	11.25	62.02	3.48	62.15	4.26	61.28	4.38	61.28	12.48	62.38
	EW-4M		EW-4S		EW-5D		EW-5M		EW-5S		EW-6M		EW-6S	
TOC ELEV	74.99		74.96		72.50		72.25		72.33		75.49		75.98	
GRD ELEV	72.18		71.96		69.80		69.55		69.53		72.69		72.98	
NORTHING	247,263.51		247,260.03		246,832.57		246,828.66		246,825.59		246,853.53		246,853.05	
EASTING	1,889,373.28		1,889,377.85		1,889,370.21		1,889,362.87		1,889,369.51		1,889,600.45		1,889,607.31	
	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV
06/16/87					10.19									
06/17/87														
06/26/87														
06/30/87	12.65	62.34	12.58	62.38	10.28	62.22	9.80	62.45	9.80	62.53			12.95	63.03
07/06/87	12.67	62.32	12.63	62.33	10.41	62.09	9.82	62.43	9.87	62.46	12.49	63.00	13.00	62.98
07/17/87	12.57	62.42	12.51	62.45	10.29	62.21	9.62	62.63	9.67	62.66	12.32	63.17	12.78	63.20
07/28/87	12.22	62.77	12.19	62.77	10.13	62.37	9.25	63.00	9.32	63.01	11.99	63.50	12.46	63.52
07/29/87	12.69	62.30	12.70	62.26	10.45	62.05	10.74	61.51	10.82	61.51	12.47	63.02		
08/13/87	12.98	62.01	12.95	62.01	10.08	62.42	10.19	62.06	10.28	62.05	13.00	62.49	13.49	62.49
08/20/87	13.10	61.89	13.07	61.89	10.26	62.24	10.37	61.88	10.43	61.90	13.17	62.32	13.66	62.32
09/14/87	12.99	62.00	12.96	62.00	10.57	61.93	10.47	61.78	10.53	61.80	13.24	62.25	13.72	62.26
09/30/87	12.90	62.09	12.88	62.08	10.56	61.94	10.41	61.84	10.48	61.85	13.11	62.38	13.61	62.37
10/19/87	13.59	61.40	13.55	61.41	10.80	61.70	10.80	61.45	10.88	61.45	13.68	61.81	14.16	61.82
11/02/87	13.30	61.69	13.25	61.71	10.52	61.98	10.45	61.80	10.54	61.79	13.36	62.13	13.85	62.13
11/12/87	13.25	61.74	12.72	62.24	10.38	62.12	10.42	61.83	10.48	61.85	13.30	62.19	13.79	62.19
01/27/88	13.08	61.91	13.05	61.91	10.44	62.06	10.10	62.15	10.16	62.17	12.94	62.55	13.43	62.55
03/17/88	13.11	61.88	12.50	61.46	10.16	62.34	10.12	62.13	10.17	62.16	12.95	62.54	13.45	62.53

3-40

TABLE 3-3 CON'T

VINELAND CHEMICAL COMPANY WATER LEVEL MEASUREMENTS

TOC ELEV	EW-10		EW-1M		EW-1S		EW-2D		EW-2M		EW-2S		EW-4D	
GRD ELEV	72.89		72.62		73.27		65.63		65.53		65.66		74.86	
NORTHING	247,964.52		247,959.34		247,953.79		247,605.43		247,559.68		247,600.90		247,265.14	
EASTING	1,889,201.52		1,889,199.13		1,889,196.90		1,889,014.59		1,889,012.74		1,889,019.54		1,889,379.31	
	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV
06/16/87														
06/17/87	10.80	62.09												
06/26/87														
06/30/87	10.13	62.76	10.36	62.26			3.48	62.15					12.37	62.49
07/06/87	10.08	62.81	10.11	62.51	10.75	62.52	3.40	62.23	4.01	61.52			12.46	62.40
07/17/87	9.82	63.07	9.87	62.75	10.43	62.84	3.12	62.51	3.60	61.93	3.69	61.97	12.39	62.47
07/28/87	10.21	62.68	10.30	62.32	10.97	62.30	3.52	62.11	3.76	61.77	4.22	61.44	12.16	62.70
07/29/87													12.52	62.34
08/13/87	10.38	62.51	10.50	62.12	11.16	62.11	3.59	62.04	4.51	61.02	4.48	61.18	12.44	62.42
08/20/87	10.50	62.39	10.59	62.03	11.26	62.01	3.74	61.89	4.33	61.20	4.42	61.24	12.65	62.21
09/14/87	10.67	62.22	10.56	62.06	11.22	62.05	3.90	61.73	4.22	61.31	4.31	61.35	12.79	62.07
09/30/87	10.65	62.24	10.45	62.17	11.09	62.18	4.33	61.30	4.76	60.77	4.70	60.96	12.72	62.14
10/19/87	11.02	61.87	11.11	61.51	11.79	61.48	4.64	60.99	5.10	60.43	5.17	60.49	13.10	61.76
11/02/87	10.73	62.16	10.84	61.78	11.51	61.76	3.94	61.69	4.37	61.16	4.50	61.16	12.10	62.76
11/12/87	10.71	62.18	10.84	61.78	11.51	61.76	3.89	61.74	3.37	62.16	3.48	62.18	13.19	61.67
01/27/88	10.39	62.50	10.59	62.03	11.26	62.01	3.64	61.99	4.31	61.22	4.38	61.28	12.66	62.20
03/17/88	10.25	62.64	10.57	62.05	11.25	62.02	3.48	62.15	4.26	61.28	4.38	61.28	12.48	62.38
	EW-4M		EW-4S		EW-5D		EW-5M		EW-5S		EW-6M		EW-6S	
TOC ELEV	74.99		74.96		72.50		72.25		72.33		75.49		75.98	
GRD ELEV	72.18		71.96		69.80		69.55		69.53		72.69		72.98	
NORTHING	247,263.51		247,260.03		246,832.57		246,828.66		246,825.59		246,853.53		246,853.05	
EASTING	1,889,373.28		1,889,377.85		1,889,370.21		1,889,362.87		1,889,369.51		1,889,600.45		1,889,607.31	
	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV
06/16/87					10.19									
06/17/87														
06/26/87	12.65	62.34	12.58	62.38	10.28	62.22	9.80	62.45	9.80	62.53			12.95	63.03
06/30/87	12.67	62.32	12.63	62.33	10.41	62.09	9.82	62.43	9.87	62.46	12.49	63.00	13.00	62.98
07/06/87	12.57	62.42	12.51	62.45	10.29	62.21	9.62	62.63	9.67	62.66	12.32	63.17	12.78	63.20
07/17/87	12.22	62.77	12.19	62.77	10.13	62.37	9.25	63.00	9.32	63.01	11.99	63.50	12.46	63.52
07/28/87	12.69	62.30	12.70	62.26	10.45	62.05	10.74	61.51	10.82	61.51	12.47	63.02		
07/29/87														
08/13/87	12.98	62.01	12.95	62.01	10.08	62.42	10.19	62.06	10.28	62.05	13.00	62.49	13.49	62.49
08/20/87	13.10	61.89	13.07	61.89	10.26	62.24	10.37	61.88	10.43	61.90	13.17	62.32	13.66	62.32
09/14/87	12.99	62.00	12.96	62.00	10.57	61.93	10.47	61.78	10.53	61.80	13.24	62.25	13.72	62.26
09/30/87	12.90	62.09	12.88	62.08	10.56	61.94	10.41	61.84	10.48	61.85	13.11	62.38	13.61	62.37
10/19/87	13.59	61.40	13.55	61.41	10.80	61.70	10.80	61.45	10.88	61.45	13.68	61.81	14.16	61.82
11/02/87	13.30	61.69	13.25	61.71	10.52	61.98	10.45	61.80	10.54	61.79	13.36	62.13	13.85	62.13
11/12/87	13.25	61.74	12.72	62.24	10.38	62.12	10.42	61.83	10.48	61.85	13.30	62.19	13.79	62.19
01/27/88	13.08	61.91	13.05	61.91	10.44	62.06	10.10	62.15	10.16	62.17	12.94	62.55	13.43	62.55
03/17/88	13.11	61.88	12.50	61.46	10.16	62.34	10.12	62.13	10.17	62.16	12.95	62.54	13.45	62.53

TABLE 3-3 CON'T

	EW-70		EW-7M		EW-7S		EW-8M		EW-8S		EW-9D		EW-9M	
TOC ELEV	72.93		72.98		73.14		78.56		78.86		81.09		81.09	
GRD ELEV	70.43		70.38		70.64		75.86		76.06		78.59		78.39	
NORTHING	246,937.59		246,931.33		246,925.67		246,907.82		246,899.88		247,056.69		247,051.94	
EASTING	1,889,931.50		1,889,931.33		1,889,934.16		1,890,061.07		1,890,063.50		1,890,436.68		1,890,435.94	
	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV
06/16/87	9.85						14.78	63.78	14.95	63.91				
06/17/87														
06/26/87	9.63	63.30	9.51	63.47	9.99	63.15	14.83	63.73	15.06	63.80	17.27	63.82	17.21	63.88
06/30/87	9.67	63.26	9.57	63.41	9.67	63.47	14.86	63.70	15.13	63.73	17.44	63.65	17.26	63.83
07/06/87	10.08	62.85	9.40	63.58	9.50	63.64	14.71	63.85	14.95	63.91	17.34	63.75	17.12	63.97
07/17/87	9.82	63.11	9.19	63.79	9.25	63.89	14.48	64.08	14.66	64.20	17.07	64.02	16.80	64.29
07/28/87	10.21	62.72	9.64	63.34	9.73	63.41	14.99	63.57	15.19	63.67	17.44	63.65	17.26	63.83
07/29/87														
08/13/87	9.75	63.18	10.07	62.91	10.18	62.96	15.42	63.14	15.62	63.24	17.19	63.90	17.55	63.54
08/20/87	10.02	62.91	10.26	62.73	10.41	62.73	14.63	63.93	15.91	62.95	17.43	63.66	17.72	63.37
09/14/87	10.31	62.62	10.22	62.76	10.38	62.76	15.63	62.93	15.94	62.92	17.69	63.40	17.78	63.31
09/30/87	10.21	62.72	9.99	62.99			15.44	63.12	15.73	63.13	17.67	63.42	17.67	63.42
10/19/87	10.47	62.46	10.70	62.28	10.84	62.30	16.03	62.53	16.30	62.56	17.88	63.21	18.07	63.02
11/02/87	10.45	62.48	10.15	62.83	10.57	62.57	15.79	62.77	16.05	62.81	17.61	63.48	17.82	63.27
11/12/87	10.08	62.85	10.39	62.59	10.50	62.64	15.74	62.82	15.98	62.88	17.52	63.57	17.80	63.29
01/27/88	10.20	62.73	10.08	62.90			15.38	63.18	15.58	63.28	17.56	63.53	17.49	63.60
03/17/88	9.95	62.98	10.10	62.88	10.20	62.94	15.38	63.18	15.86	63.00	17.35	63.74	17.59	63.50
	EW-9S		EW-10D		EW-10M		EW-10S		EW-11M		EW-11S		EW-12M	
TOC ELEV	80.96		72.13		72.31		72.38		77.99		77.66		78.92	
GRD ELEV	78.16		69.63		69.61		69.68		74.99		74.86		75.92	
NORTHING	247,046.67		246,771.43		246,781.35		246,776.61		246,567.63		246,568.14		246,598.96	
EASTING	1,890,435.45		1,889,051.31		1,889,051.78		1,889,062.25		1,889,772.67		1,889,716.60		1,890,590.84	
	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV
06/16/87	17.03	63.93												
06/17/87			10.08	62.05	10.82	61.49	10.77	61.61					14.02	64.90
06/26/87			10.21	61.92	10.72	61.59	10.77	61.61						
06/30/87	17.07	63.89	10.37	61.76	10.77	61.54	10.82	61.56					14.23	64.69
07/06/87	16.93	64.03	10.19	61.94	10.61	61.70	10.67	61.71					14.28	64.64
07/17/87	16.60	64.36	9.98	62.15	10.23	61.08	10.26	62.12	14.06	63.93	13.66	64.00	14.23	64.69
07/28/87	17.05	63.91	10.35	61.78	10.69	61.62	10.76	61.62	13.74	64.25	13.30	64.36	13.86	65.06
07/29/87									14.15	63.84	13.75	63.91	14.22	64.70
08/13/87	17.37	63.59	10.24	61.89	11.04	61.27	11.13	61.25						
08/20/87	17.53	63.43	10.44	61.69	11.19	60.12	11.27	61.11	14.99	63.00	14.68	62.98	14.63	64.29
09/14/87	17.90	63.06	10.63	61.54	11.23	61.08	11.40	60.98	14.20	63.79	14.68	62.98	14.89	64.03
09/30/87	17.51	63.45			11.34	60.97			15.44	62.55	15.19	62.47	15.20	63.72
10/19/87	17.92	63.04			11.53	61.78			15.38	62.61	15.07	62.59	15.19	63.73
11/02/87	17.66	63.30	11.44	60.69	11.11	61.20	11.61	60.77	15.78	62.21	15.47	62.19	15.43	63.49
11/12/87	17.62	64.34	10.61	61.52	11.11	61.20	11.24	61.14	15.46	62.53	15.15	62.51	15.19	63.73
01/27/88	17.30	63.66	10.50	61.63	11.14	61.17	11.20	61.18	15.40	62.59	15.08	62.58	15.19	63.73
03/17/88	17.40	63.56	10.44	61.69	10.86	61.45	10.90	61.48	14.83	63.16	14.49	63.17	14.64	64.28
			10.17	61.96	10.86	61.45	10.91	61.47	14.76	63.23	14.43	63.23	15.06	63.86

TABLE 3-3 CON'T

	EW-12S		EW-13M		EW-13S		EW-14M		EW-14S		EW-15D		EW-15M	
TOC ELEV	79.43		71.85		72.18		70.72		70.92		73.18		73.25	
GRD ELEV	76.33		69.25		69.38		67.32		67.72		70.68		70.45	
NORTHING	246,609.28		246,392.88		246,381.96		246,220.11		246,221.71		245,937.37		245,939.30	
EASTING	1,890,591.09		1,889,005.83		1,889,016.77		1,889,355.90		1,889,347.47		1,890,140.12		1,890,144.47	
	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV
06/16/87	14.54	64.89					7.84	62.88	8.03	62.89	9.48	63.70		
06/17/87														
06/26/87	14.70	64.73	10.14	61.71	10.42	61.76	8.07	62.65	8.23	62.69			8.68	64.56
06/30/87	14.75	64.68	10.49	61.38	10.20	61.98	8.13	62.59	8.21	62.71			8.94	64.31
07/06/87	14.74	64.69	10.08	61.77	10.37	61.81	8.01	62.71	8.20	62.72			9.02	64.23
07/17/87	14.35	65.08	9.64	62.21	9.93	62.25	7.58	63.14			9.78	63.40	9.00	64.25
07/28/87	14.70	64.73	10.15	61.70	10.44	61.74	8.03	62.69	7.79	63.13	9.55	63.63	8.67	64.58
07/29/87									8.23	62.69	9.80	63.38	8.92	64.33
08/13/87	15.11	64.32	10.50	61.35	10.81	61.37	8.46	62.26	8.66	62.26				
08/20/87	15.37	64.06	10.68	61.17	10.99	61.19	8.73	61.99	8.89	62.03	9.53	63.65	9.42	63.83
09/14/87	15.64	63.79	10.91	60.94	11.25	60.93	9.04	61.68	9.25	61.67	9.75	63.43	9.65	63.60
09/30/87	15.71	63.72	10.93	60.92							10.18	63.00	10.15	63.10
10/19/87	15.90	63.53	10.95	60.90	11.42	60.76	9.27	61.45	9.48	61.44	10.18	63.00	10.23	63.02
11/02/87	15.69	63.74	10.68	61.17	11.00	61.18	8.90	61.82	9.09	61.83	10.39	62.79	10.39	62.86
11/12/87	15.68	63.75	10.69	61.16	11.02	61.16	8.90	61.82	9.10	61.82	10.13	63.05	10.14	63.11
01/27/88	15.18	64.25	10.27	61.58	10.57	61.61	8.37	62.35	8.56	62.36	10.00	63.18	10.16	63.09
03/17/88	14.60	64.83	10.22	61.63	10.53	61.65	8.25	62.47	8.45	62.47	10.17	63.01	9.54	63.71
											9.73	63.45	9.30	63.95
	EW-15S		DNSTRM GAUGE		NEW DNSTRM		UPSTRM GAUGE		NEW UPSTRM		MW-1		MW-2	
TOC ELEV	73.56		67.58		66.14		67.99		62.67		76.23		74.71	
GRD ELEV	70.66										74.43		73.01	
NORTHING	245,941.79		247,691.68		247,683.74		247,192.70		247,150.08		246,857.24		246,866.39	
EASTING	1,890,139.00		1,889,029.56		1,888,949.44		1,890,251.80		1,890,120.01		1,890,061.83		1,889,761.80	
	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV	DTW	ELEV
06/16/87														
06/17/87														
06/26/87	9.12	64.44												
06/30/87	9.28	64.28												
07/06/87	9.27	64.29												
07/17/87	8.98	64.58	1.30	62.88			1.30	63.29						
07/28/87	9.22	64.34	0.75	62.33			0.80	62.79						
07/29/87														
08/13/87	9.69	63.87	1.10	62.68			0.70	62.69			12.39	63.84	11.25	63.46
08/20/87	9.95	63.61	0.70	62.28			0.50	62.49			12.91	63.32	11.88	62.83
09/14/87	10.45	63.11	1.10	62.68			0.87	62.86			13.22	63.01	12.06	62.65
09/30/87	10.52	63.04			2.90	61.04	0.88	62.87					12.09	62.62
10/19/87	10.69	62.87			3.28	61.42			1.10	60.77	13.18	63.05	12.38	62.33
11/02/87	10.46	63.10			2.60	60.74			2.20	61.87	12.49	63.74	12.57	62.14
11/12/87	10.47	63.09			2.90	61.04			2.40	62.07	13.59	62.64	12.28	62.43
01/27/88	9.85	63.71			2.90	61.04			2.40	62.07	13.32	62.91	12.20	62.51
03/17/88	9.59	63.97			2.90	61.04			2.20	61.87	13.27	62.96	11.82	62.89
					2.90	61.04			2.30	61.97	12.80	63.43	11.83	62.92
											12.81	63.42		

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TABLE 3-3 CON'T

	MW-3		MW-4		MW-5		MW-6		MW-7		MW-8		MW-9	
	TOC ELEV	72.96	TOC ELEV	76.00	TOC ELEV	76.48	TOC ELEV	73.95	TOC ELEV	75.69	TOC ELEV	71.95	TOC ELEV	75.94
	GRD ELEV	71.46	GRD ELEV	74.30	GRD ELEV	74.33	GRD ELEV	72.15	GRD ELEV	73.09	GRD ELEV	69.85	GRD ELEV	73.84
	NORTHING	246,330.97	NORTHING	246,313.96	NORTHING	246,590.20	NORTHING	246,328.74	NORTHING	246,546.71	NORTHING	246,873.53	NORTHING	246,824.39
	EASTING	1,889,383.58	EASTING	1,890,156.31	EASTING	1,889,539.45	EASTING	1,889,235.68	EASTING	1,889,982.03	EASTING	1,889,516.31	EASTING	1,889,993.96
	DTW ELEV		DTW ELEV		DTW ELEV		DTW ELEV		DTW ELEV		DTW ELEV		DTW ELEV	
06/16/87														
06/17/87														
06/26/87														
06/30/87														
07/06/87														
07/17/87														
07/28/87														
07/29/87	10.22	62.74	11.59	64.41	13.38	63.10	9.46	64.49	10.64	65.05	9.18	62.77	11.25	64.69
08/13/87	10.65	62.31	12.14	63.86	13.95	62.53	12.03	61.92	12.01	63.68	9.60	62.35	12.70	63.24
08/20/87	10.90	62.06	12.46	63.54	14.18	62.30	12.11	61.84	12.24	63.45	9.78	62.17	13.08	62.86
09/14/87	11.18	61.78	12.78	63.32	14.40	62.08			12.51	63.18	9.81	62.14	12.98	62.96
09/30/87	11.23	61.73	12.84	63.16	14.36	62.12	12.54	61.41	12.49	63.20	12.50	59.45	12.89	63.05
10/19/87	11.44	61.52	13.05	62.95	14.69	61.79	12.73	61.22	12.90	62.79	10.26	61.69	13.41	62.53
11/02/87	11.05	61.91	12.81	63.19	14.34	62.14	11.74	62.21	12.62	63.07	9.93	62.02	13.15	62.79
11/12/87	11.05	61.91	12.80	63.20	14.31	62.17	12.28	61.67	12.45	63.24	9.87	62.08	13.07	62.87
01/27/88	10.53	62.43	12.13	63.87	13.81	62.67	11.81	62.14	11.59	64.10	9.54	62.41	12.57	63.37
03/17/88	10.46	62.50	12.99	63.01	13.78	62.70	11.36	62.59	11.38	64.31	9.56	62.39	12.54	63.40
	MW-10		MW-11		HART									
	TOC ELEV	75.90	TOC ELEV	75.20	TOC ELEV	76.58								
	GRD ELEV	74.30	GRD ELEV	73.60	GRD ELEV	73.99								
	NORTHING	246,853.47	NORTHING	246,804.47	NORTHING	246,849.01								
	EASTING	1,889,992.22	EASTING	1,889,995.34	EASTING	1,889,942.67								
	DTW ELEV		DTW ELEV		DTW ELEV									
06/16/87														
06/17/87														
06/26/87														
06/30/87														
07/06/87														
07/17/87														
07/28/87														
07/29/87	15.95	59.95	11.07	64.13										
08/13/87	12.71	63.19	11.89	63.31										
08/20/87	16.65	59.25	12.22	62.98										
09/14/87	13.03	62.87	12.18	63.02	14.10	62.48								
09/30/87	12.83	63.07	12.06	63.14										
10/19/87	13.39	62.51	13.62	61.58										
11/02/87	13.12	62.78	12.36	62.84										
11/12/87	13.07	62.83	12.26	62.94	13.75	62.83								
01/27/88	12.60	63.30	11.69	63.51										
03/17/88	12.61	63.29	12.54	63.57	13.86	62.72								

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It should be noted that this dark grey marker bed was identified by previous ViChem reports as being a continuous, 15 foot thick, clay layer that separated the middle sand from the underlying sands pumped by the ViChem production well. However a considerable amount of sand was found in this dark grey zone in this investigation.

It should also be noted that Ebasco did not determine the vertical permeability of the banded zone separating the upper and medium sand as part of this investigation. This zone consists of sands with interspersed clay laminae approximately 10 to 15 feet thick. This zone may act as one unit, however in any given sample it is heterogeneous and difficult to test for permeability.

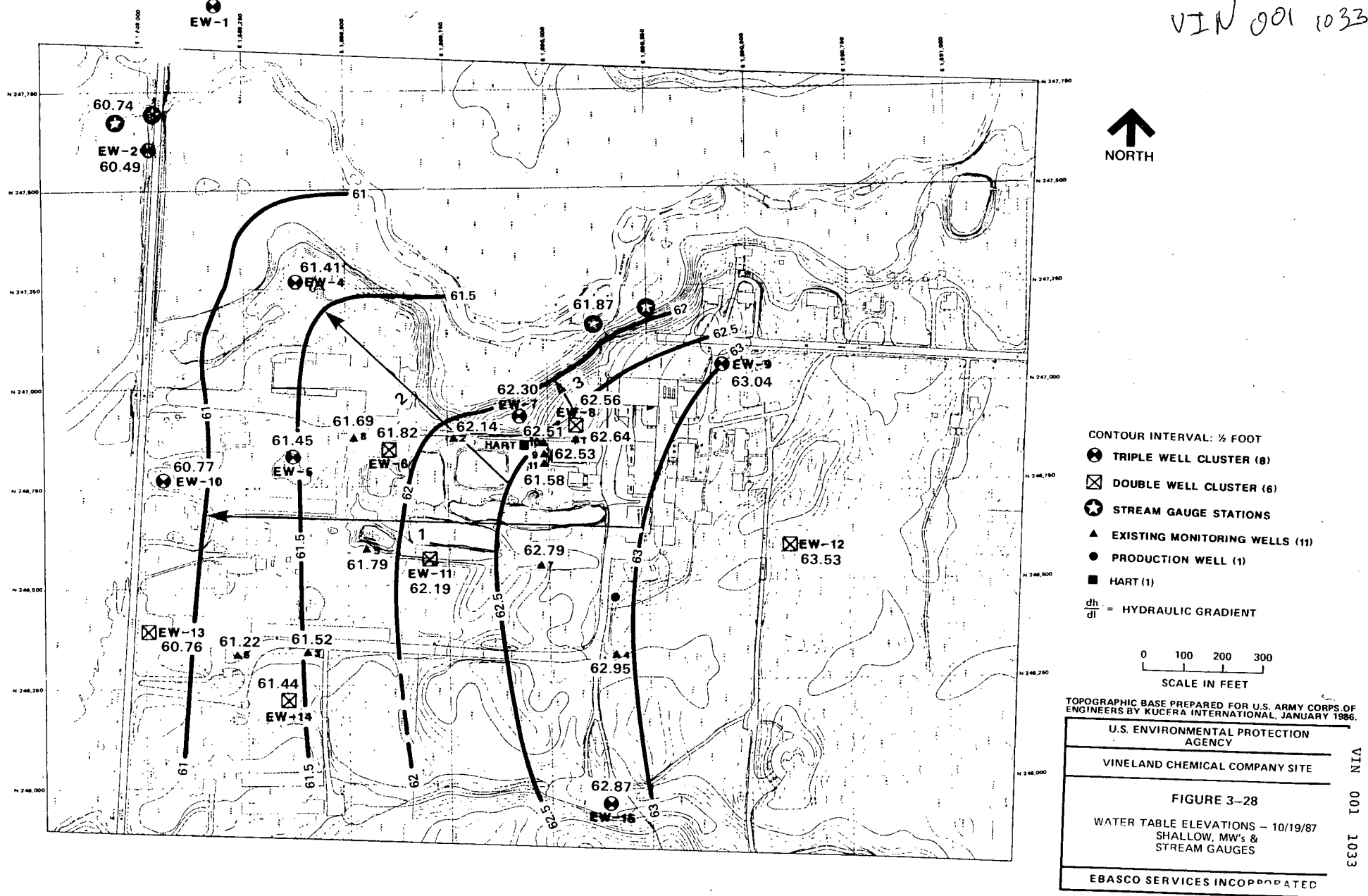
3.4.1.2 Groundwater Contours

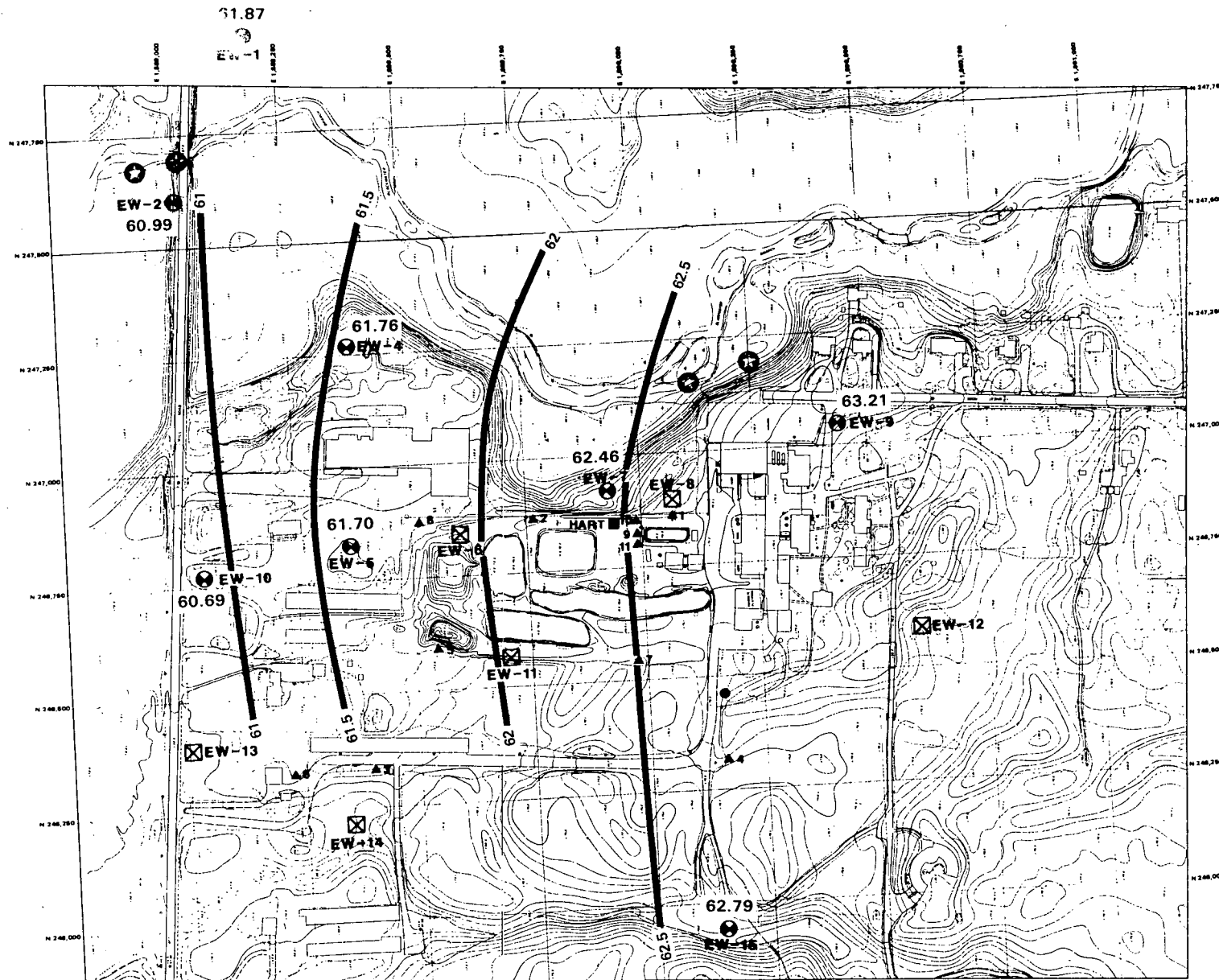
Three representative sets of water levels were selected for presenting groundwater contours. Water table contours in the upper sand aquifer and potentiometric surface maps of the middle sand aquifer are plotted for 10/19/87, 11/2/87 and 1/27/88 in Figures 3-28 through 3-33. To contour the water levels, the 3-point structural contouring method was implemented. Separate plots were created for the water levels in the upper sand from the water levels in the middle and lower sand because the water levels were distinctly different. Shallow well water levels were used for the upper sand aquifer plots since the shallow and medium well water levels were similar. A one-half foot contour interval was used.

Conclusions may be made about the characteristics of the upper sand and the middle sand aquifers. Within the upper sand the predominant direction of groundwater flow is north to northwest. There is approximately a three foot drop in water level between the eastern part of the site and the western side of the site. As seen in Figures 3-28, 3-30 and 3-32, water levels in the upper sand aquifer are higher than in the Blackwater Branch. The groundwater in the upper sand aquifer appears to be recharging the Blackwater Branch.

No obvious groundwater mounding is seen in the vicinity of the unlined lagoon UL-A. This unlined lagoon receives treated discharge water from the treatment plant and also receives the non-contact cooling water discharge. There is a general bending of the groundwater contours in the lagoon area but not enough to indicate mounding. It should be pointed out that the flow rate of the discharge water entering the unlined lagoon was not measured. It is possible that mounding would occur at a high flowrate, but this cannot be quantified at this time.

The middle sand aquifer has a predominant direction of flow to the west. There is approximately a two foot water level difference between the eastern side of the site and the western side of the site. It is unknown whether there is a hydraulic connection between the middle sand and the Blackwater Branch, although there is an upward hydraulic gradient between the two.





- CONTOUR INTERVAL: 1/2 FOOT
- TRIPLE WELL CLUSTER (8)
 - ⊠ DOUBLE WELL CLUSTER (6)
 - ★ STREAM GAUGE STATIONS
 - ▲ EXISTING MONITORING WELLS (11)
 - PRODUCTION WELL (1)
 - HART (1)

0 100 200 300
SCALE IN FEET

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

U.S. ENVIRONMENTAL PROTECTION AGENCY

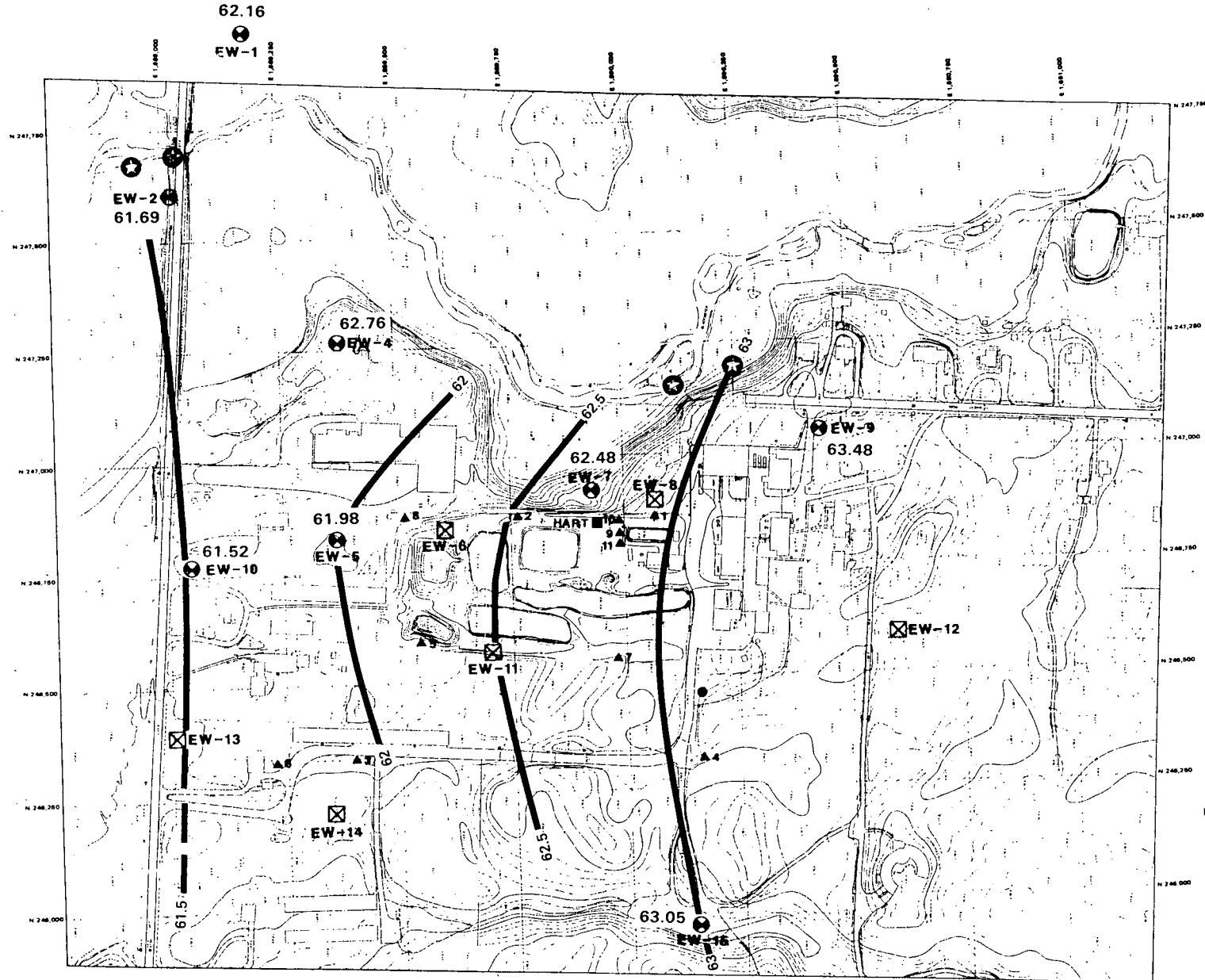
VINELAND CHEMICAL COMPANY SITE

FIGURE 3-29

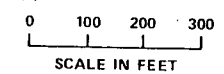
WATER LEVELS - 10/19/87
DEEP WELLS

EBASCO SERVICES INCORPORATED

VIN 001 1034



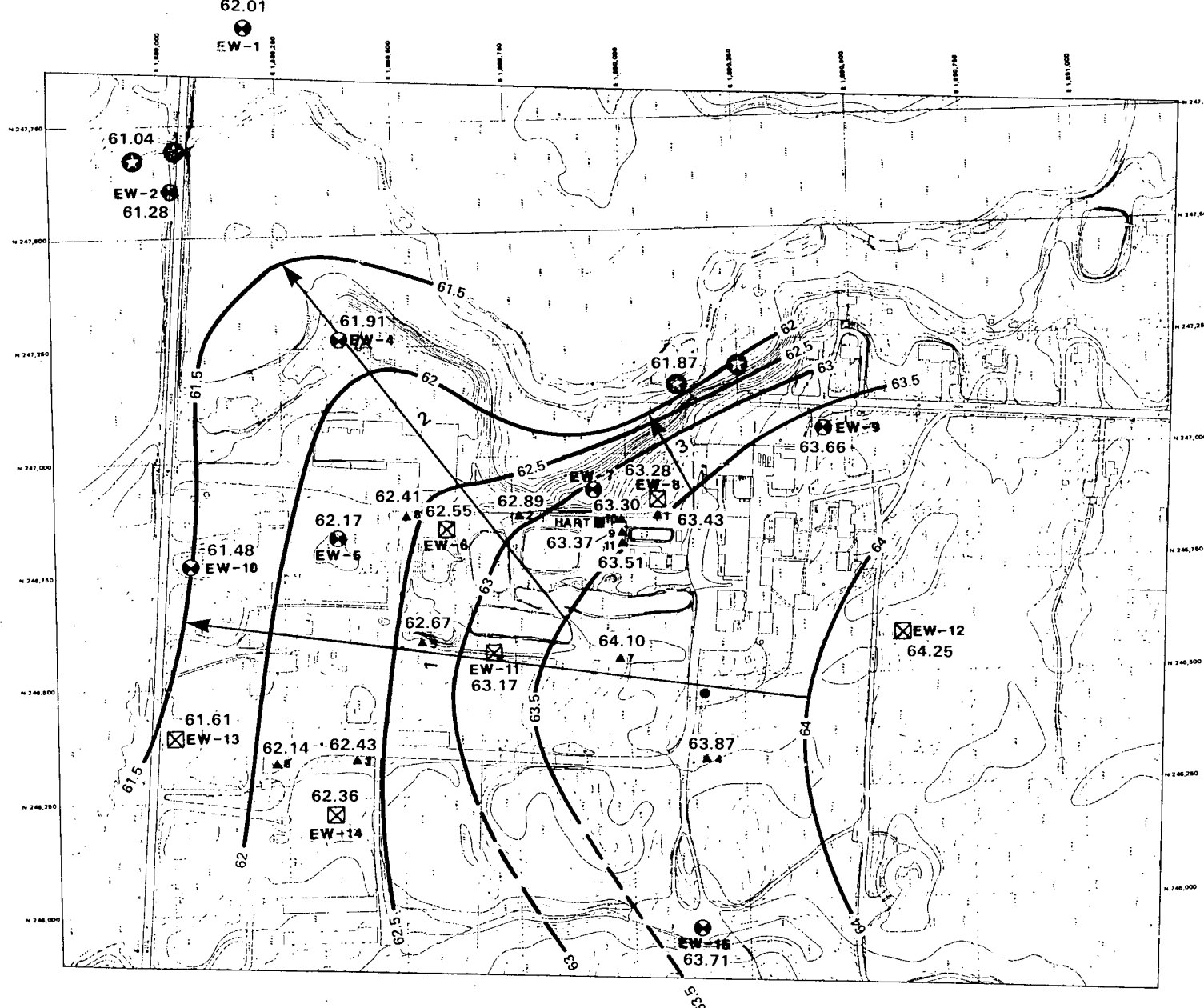
- CONTOUR INTERVAL: 1/2 FOOT
- ☉ TRIPLE WELL CLUSTER (8)
 - ⊠ DOUBLE WELL CLUSTER (6)
 - ★ STREAM GAUGE STATIONS
 - ▲ EXISTING MONITORING WELLS (11)
 - PRODUCTION WELL (1)
 - HART (1)



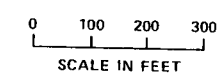
TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-31 WATER LEVELS - 11/2/87 DEEP WELLS
EBASCO SERVICES INCORPORATED

VIN 001 1036



- CONTOUR INTERVAL: 1/2 FOOT
- TRIPLE WELL CLUSTER (8)
 - ⊠ DOUBLE WELL CLUSTER (6)
 - ★ STREAM GAUGE STATIONS
 - ▲ EXISTING MONITORING WELLS (11)
 - PRODUCTION WELL (1)
 - HART (1)
- $\frac{dh}{dl}$ = HYDRAULIC GRADIENT

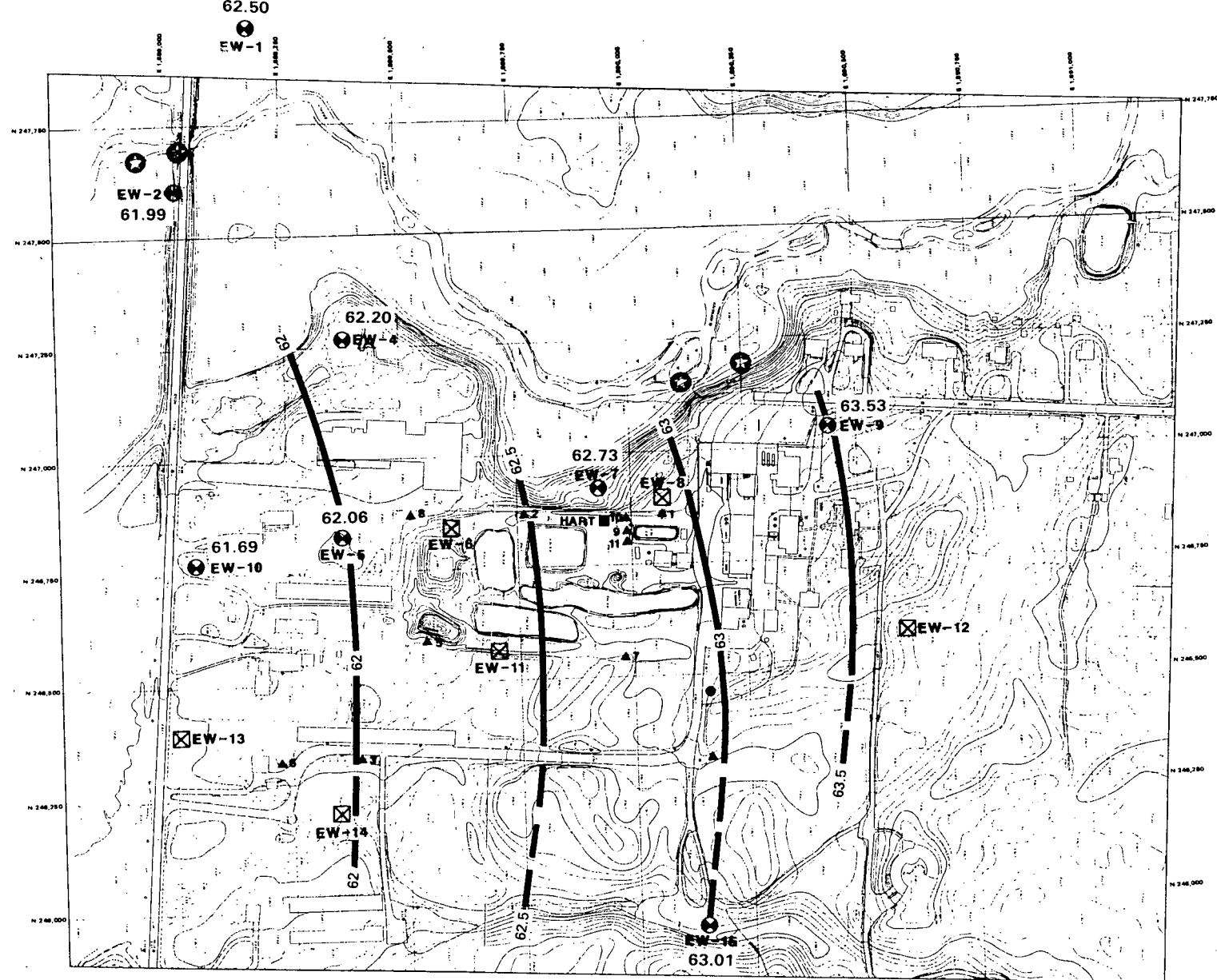


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U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 3-32
WATER TABLE ELEVATIONS - 1/27/88 SHALLOW, MW's & STREAM GAUGES
EBASCO SERVICES INCORPORATED

VIN 001 1037

VIN 0011038



CONTOUR INTERVAL: 1/2 FOOT

- TRIPLE WELL CLUSTER (8)
- ⊠ DOUBLE WELL CLUSTER (6)
- ★ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART

0 100 200 300

SCALE IN FEET

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U.S. ENVIRONMENTAL PROTECTION AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 3-33

WATER LEVELS - 1/27/88
DEEP WELLS

EBASCO SERVICES INCORPORATED

VIN 001 1038

3.4.1.3 Aquifer Tests of Upper and Middle Sands

During both groundwater sampling efforts, the Ebasco and ViChem wells were purged before sampling. The water level recoveries after purging were measured. The recoveries were plotted to attempt to determine the aquifer's transmissivity.

These single well tests produced very poor data. The transmissivities from these plots were too low, approximately 1,000 gallons per day per foot (gpd/ft), and did not fit with known regional values or the assumed values based on grain sizes within the aquifers.

A pumping test of MW-10 was performed on 7/28/87. ViChem was pumping this well at 25 gallons per minute (gpm) as part of their groundwater treatment system. The water was discharged into the lined lagoon LL-2. Ebasco measured the drawdown and recovery in MW-10 as well as in MW-9 and MW-11 for eight hours of pumping. The analyses of the pumping test are found in Appendix E.

Throughout the lagoon area, the saturated thickness of the upper aquifer is approximately 50 feet. MW-9 is located approximately one-half an aquifer thickness away from MW-10, 29.5 feet, while MW-11 is located approximately one aquifer thickness away from MW-10, 49.5 feet. For this reason, the analyses performed on MW-11 were considered the most reliable. Time versus drawdown were plotted for MW-11 and analyzed by the Theis method (Theis, 1935). For MW-9, time versus drawdown were plotted and analyzed by the Jacob and Theis methods (Cooper and Jacob, 1946). For the pumping well, MW-10, residual drawdown vs. a t/t' and drawdown and recovery versus time were plotted and analyzed by the Jacob method.

Table 3-4 summarizes the values from the pumping test analyses. The three drawdown plots for MW-11 produced transmissivities of 100,526 gpd/ft, 119,375 gpd/ft and 137,500 gpd/ft. The storage coefficient from these plots was 0.1, 0.86 and 0.056. The most representative transmissivity value from these plots was estimated to be 110,000 gpd/ft and the most representative storage coefficient was estimated to be 0.1. These values were used during groundwater modeling.

The pumping well MW-10 only partially intersects the aquifer. Therefore, it was necessary to evaluate the effects of partial penetration on this pumping test. When the pumping well does not penetrate the entire aquifer thickness, and when the aquifer is unconfined and the time of pumping is relatively short, Hantush's (1964) correction method for steady state flow in unconfined partially penetrated aquifers may be used to determine possible partial penetration effects. The calculation was implemented for the drawdown in MW-11 by replacing drawdown, s , by $s - s^2/2d$ where d is the depth of penetration. The effects of this correction on drawdown were insignificant.

TABLE 3-4

MW-10 PUMPING TEST: 7/28/87

WELL	PLOT	(gpd/ft) TRANSMISSIVITY	STORAGE COEFFICIENT	METHOD OF ANALYSIS
MW-11	TIME-DRAWDOWN	137,500	0.056	JACOB
MW-11	TIME-DRAWDOWN	119,375	0.86	THEIS
MW-11	t/r ² -DRAWDOWN	100,526	0.10	THEIS
MW-9	TIME-DRAWDOWN	132,000	6.4x10 ⁻⁴	JACOB
MW-9	TIME-DRAWDOWN	168,529	8.6x10 ⁻⁵	THEIS
MW-10 (pumping well)	RESIDUAL DD-t/t'	124,528		JACOB
	DD (Recovery)-t/t'	120,000		JACOB

Pumping Rate, Q = 25 gpm for 8 hours

 r_o MW-9 = 29.5 ft. r_o MW-11 = 49.5 ft.

VALUES USED FOR MODELING:

T = 110,000 gpd/ft

S = 0.1

The two drawdown plots for MW-9 produced transmissivities of 132,000 gpd/ft and 168,529 gpd/ft and storage coefficients of 6.4×10^{-4} and 8.6×10^{-5} . These values were considered unrepresentative due to the proximity of MW-9 to the pumping well. The two drawdown plots for the pumping well produced transmissivities of 124,528 gpd/ft and 120,000 gpd/ft.

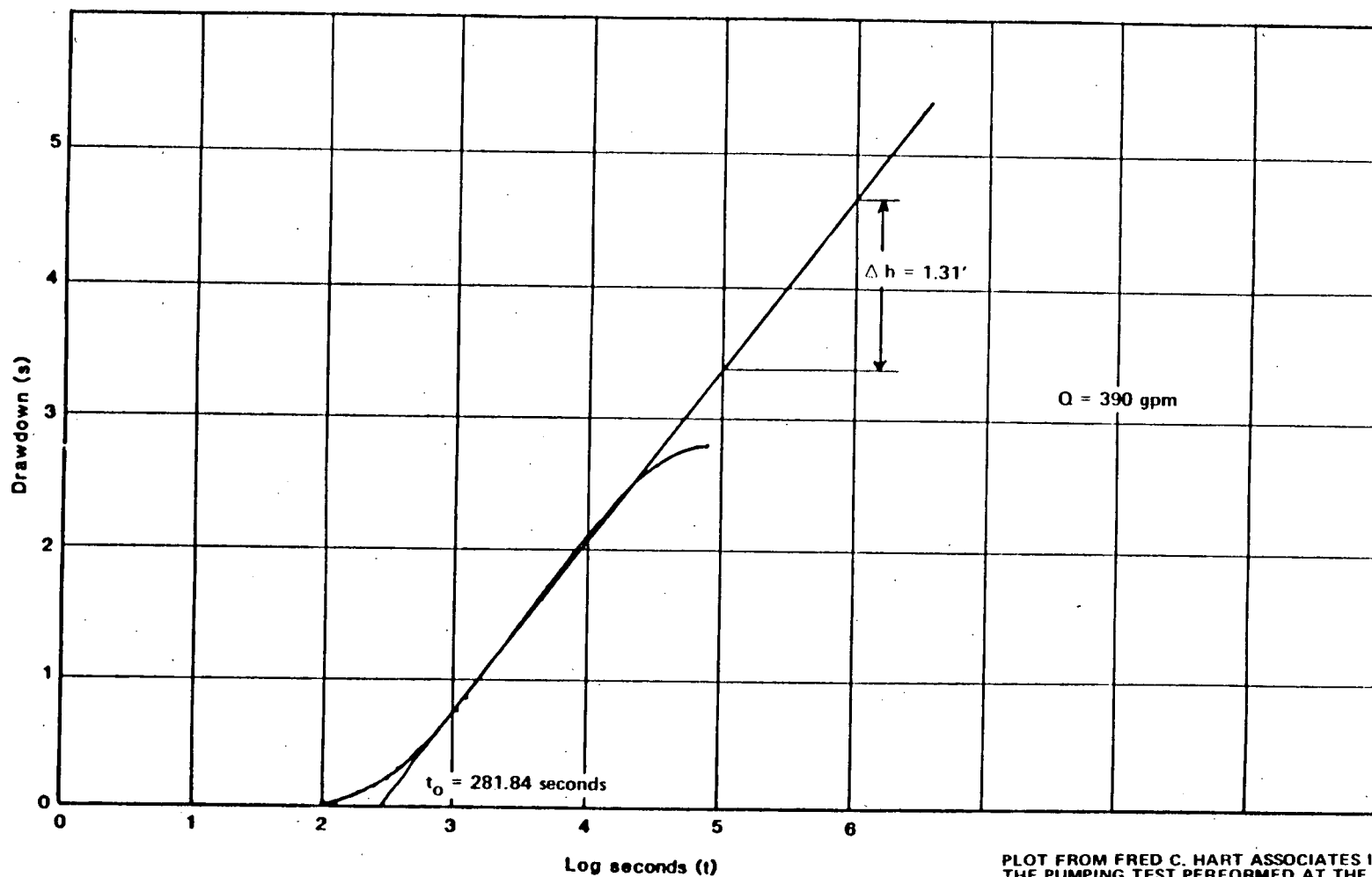
Assuming an aquifer thickness of 50 feet and a transmissivity of 110,000 gpd/ft from MW-11, the hydraulic conductivity (K) would be 2200 gpd/ft² (294 feet per day).

Fred C. Hart Associates, Inc. conducted a 24-hour pumping test on ViChem's production well in September, 1986. Water level measurements were recorded on four observation wells, the Hart well, MW-7, MW-10, and MW-11, in addition to the pumping well. The pumping rate was approximately 390 gpm and the pumped water was discharged into the unlined lagoon, UL-A, that receives treatment water. The semi-log drawdown plot for the deep Hart well, prepared by Fred C. Hart Associates for ViChem, is presented in Figure 3-34.

The average transmissivity calculated from the drawdown in the Hart observation well is approximately 70,000 gpd/ft. Water levels rose slightly in the shallow monitoring wells indicating a delayed mounding effect due to the discharged water. Water table elevations also rose north of the discharging lagoon indicating groundwater in the shallow aquifer was moving towards the Blackwater Branch.

A conclusion presented in the report of this pumping test was that the "clay layer" (identified in this RI report as the dark grey marker bed at the top of the lower sand) was an impermeable boundary, and prevented the downward migration of groundwater into the lower sand. However, Ebasco reviewed the same data and observed a deflection on the drawdown curve shown in Figure 3-34 at 4.3 log seconds (approximately 5.5 hours) after pumping began. This deflection may be due to leakage across the dark grey marker bed at the top of the lower sand, or a recharge boundary. In either case, the data show that leakage across the dark grey marker bed could be occurring, and that the lower sand may not be totally isolated from the upper aquifers.

Previous tests and literature values for the upper sand aquifer can be compared to the values determined during this RI. A pumping test conducted for ViChem (Lennon, 1982) was based on the pumping of MW-9 at 100 gpm. MW-10 and MW-11 were monitored during the test. Transmissivity in the area of the lagoons was determined to be 50,000 gpd/ft, storage coefficient values ranged between 0.04 and 0.1. The hydraulic gradient was determined to be 0.005 to 0.010 toward the Blackwater Branch.



PLOT FROM FRED C. HART ASSOCIATES INC. REPORT ON
THE PUMPING TEST PERFORMED AT THE VINELAND
CHEMICAL SITE, SEPTEMBER 1986.

U.S. ENVIRONMENTAL PROTECTION
AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 3-34

SEMILOG PLOT OF HART WELL
DRAWDOWN DURING 24 HOUR PUMPING TEST

EBASCO SERVICES INCORPORATED

The Cohansey-Kirkwood aquifer has been tested within Cumberland County. Transmissivity was determined from a pumping test to be about 30,000 gpd/ft, the coefficient of storage was calculated to be about 3.0×10^{-4} at a site where the aquifer was 25 feet thick.

3.4.1.4 Groundwater Flow and Direction

GROUNDWATER FLOW

Table 3-5 presents a summary of the groundwater flow off of the site from the upper sand. The calculations used to determine the groundwater flow and velocity are found in Appendix F.

Using Darcy's equation the average groundwater flow rate through the site was determined from:

$$Q = KIA$$

Q = Groundwater flow rate per unit time, gpd

K = hydraulic conductivity, gpd/ft²

I = $\frac{dh}{dl}$ = hydraulic gradient

A = cross-sectional area (at a right angle to the flow direction) through which the flow occurs, ft²

The flow rate and velocity were calculated using the upper sand water levels from 10/19/87, 11/2/87 and 1/27/88. There are three specific directions of flow shown on the groundwater contour plots (Figures 3-28, 3-30, 3-32). Vector 1 is from the lagoon area west towards Mill Road, Vector 2 is from the lagoon area northwest towards the EW-4 cluster, and Vector 3 is from the lagoon area north towards the Blackwater Branch. Groundwater flow and groundwater velocity were calculated in the three vector directions for 10/19/87, 11/2/87 and 1/27/88. The sum of the three flows for each of the three days were 490,916 gpd for 10/19/87, 367,141 gpd for 11/12/87 and 618,987/gpd for 1/27/88. The average groundwater flow underneath the site was estimated to be 492,351 gpd.

GROUNDWATER VELOCITY

The velocity was calculated for each of the three vector directions for the three days. The velocity of groundwater flow was calculated using the hydraulic conductivity, the hydraulic gradient and the effective porosity. The effective porosity of this clean sand aquifer was estimated as being 30%. The equation used was:

$$\bar{v} = \frac{K(\frac{dh}{dl})}{n}$$

TABLE 3-5

GROUNDWATER FLOW OFF-SITE FROM UPPER SAND

<u>Date</u>	<u>Q₁[*]</u>	<u>Q₂[*]</u>	<u>Q₃[*]</u>	<u>Total</u>
10/19/87	158,922	70,753	261,241	490,916
11/21/87	150,093	70,753	146,295	367,141
1/27/88	<u>158,922</u>	<u>94,337</u>	<u>365,738</u>	<u>618,997</u>
Average	156,000	78,000	258,000	492,000

* All flows in gallons per day along vectors 1, 2 and 3
See Appendix F for calculations

Where \bar{V} = groundwater velocity
 K = hydraulic conductivity
 $\frac{dh}{dl}$ = hydraulic gradient
 n = effective porosity of the porous medium

Appendix F presents the velocity calculations for each vector (V_1 , V_2 , V_3) and an average velocity for each direction. The velocity to the west was approximately 2.0 ft/day, the velocity towards the EW-4 cluster was approximately 1.8 ft/day and the groundwater velocity to the Blackwater Branch was approximately 5.5 ft/day. The average groundwater flow velocity off the site was estimated to be approximately two to five feet per day through the upper sand. The aquifer properties of the middle and lower sands were not evaluated, since no groundwater contamination was detected in these zones.

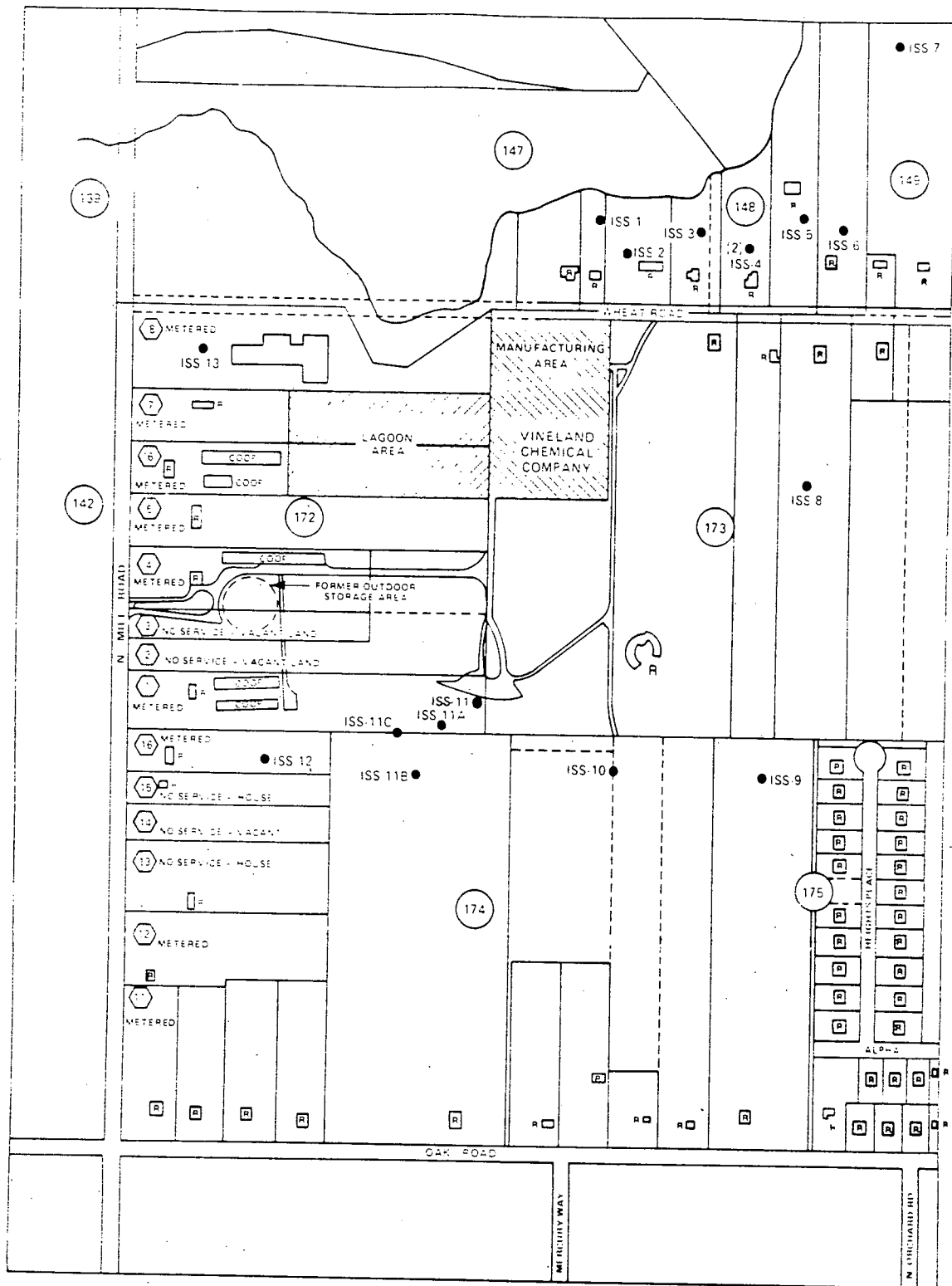
3.5 GROUNDWATER USAGE

The City of Vineland Water - Sewer Utility provided a list of property owners who have frontage on North Mill Road from Oak Road north to the Blackwater Branch crossing and who also use the available public water. The water main has been installed along this stretch of the road since 1968. The City Tax Assessor's Office was contacted to determine if an occupied residence was listed for each lot. A field check was also performed to verify the number of occupied dwellings and their source of potable water. All of this was done to determine if local residents could be impacted by groundwater emanating from the ViChem plant site.

The results of this information gathering are shown in Figure 3-35, which presents the properties, whether the property is connected to public water supplies (indicated by "metered"), and whether an occupied residence exists on the property.

The figure shows that two residences (Block 174, Lot 15 and Block 174, Lot 13) are not served by the public water line. These two properties are not directly downgradient of the ViChem plant site. The remaining properties are either served by the public water line ("metered") or do not contain an occupied dwelling ("vacant").

Figure 3-36 shows the pumping stations for the City of Vineland Water Supply. From the information gathered in this RI, it appears that none of the water supply wells are downgradient of the ViChem plant site. The closest water supply well, #7, is located approximately 6500 feet south of the ViChem plant on Mill Road. All of the City of Vineland's water supply wells are reportedly screened below the dark grey marker bed seen at the top of the lower sand at the ViChem plant site.



LEGEND:

- 172 BLOCK NUMBER
- SOIL SAMPLING LOCATIONS
- R RESIDENCES
- ⬡ LOT NUMBER



SCALE IN FEET

BASE MAP PREPARED BY CITY ENGINEER, WILLIAM G. AUSTIN, CITY OF VINELAND, OCTOBER 1971.

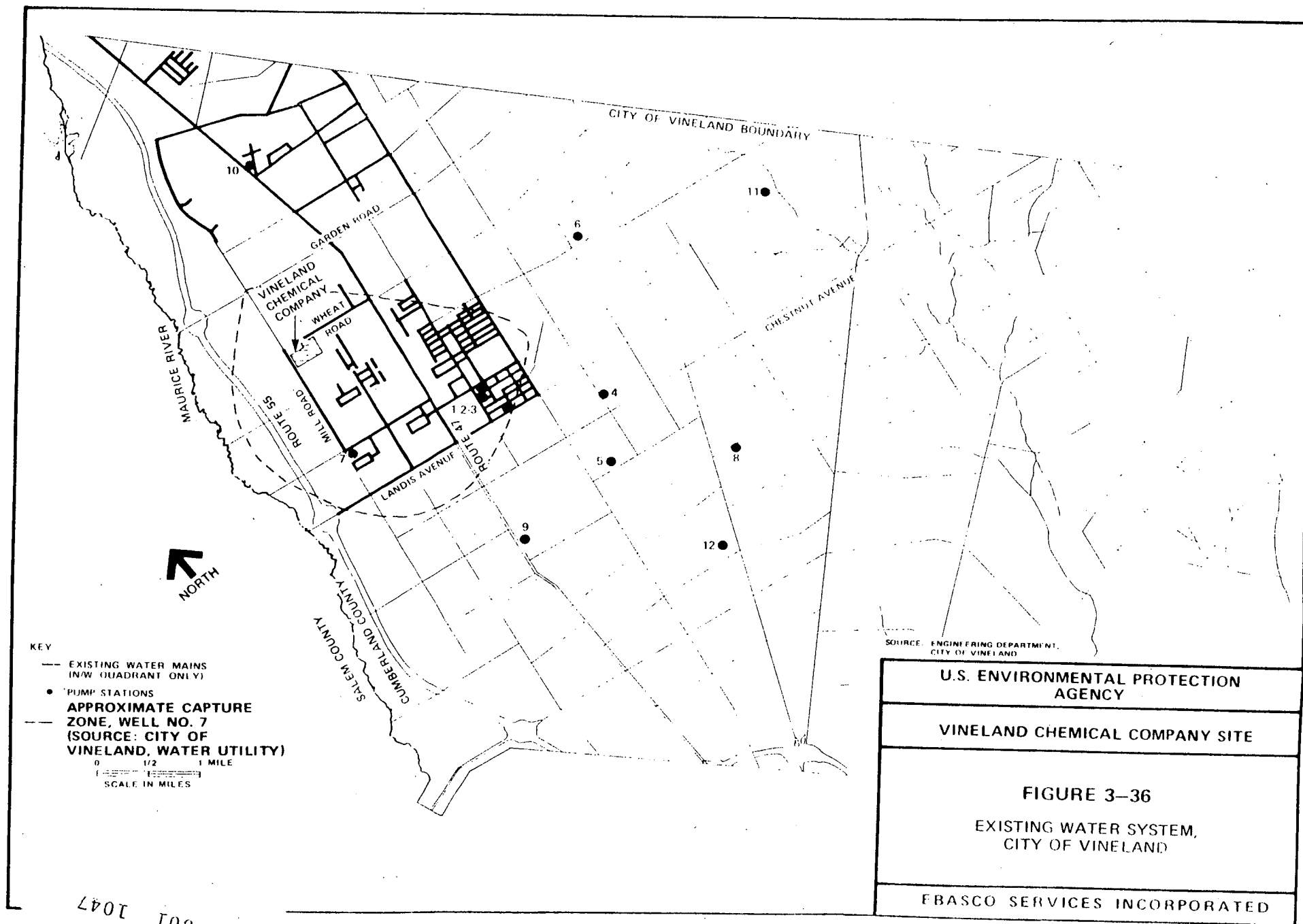
U.S. ENVIRONMENTAL PROTECTION AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 3-35

RESIDENTIAL SOIL SAMPLING LOCATIONS AND WATER SUPPLY ALONG N MILL ROAD

EBASCO SERVICES INCORPORATED



VIN 001 1047

The City of Vineland commissioned an investigation into the hydrologic regime near its wells #7 and #10. The purpose was to determine the source(s) of TCE contamination in these wells, and to recommend technologies to remove the TCE.

As part of this investigation, a pumping test was conducted on well #7. The distance-drawdown plot revealed a cone of influence extending approximately 5,200 feet from the well under apparently steady-state conditions after pumping for 48 hours at 1,000 gpm. The report estimated that the capture zone, the distance that the well would draw contamination back to it, was approximately 2,250 feet downgradient, and approximately 3.14 times this distance parallel to the gradient. The estimated capture zone is shown in Figure 3-36.

As shown in the figure, the estimated capture zone extends to the ViChem plant site. It must be recalled, however, that the pumping well is screened in an aquifer that is stratigraphically below the contaminated upper sand aquifer at the ViChem plant site. Since the water levels in both the upper and middle sand aquifers showed no apparent bending towards Vineland's Well #7, it is unlikely that this well is actually drawing water from the contaminated upper sand aquifer toward it. The capture zone is more likely within the lower stratigraphic unit that Vineland's Well #7 is actually screened in. However, as a precautionary measure, it is recommended in Section 8.0 that additional monitoring wells be installed in the upper sand aquifer south of the ViChem plant to insure that contamination is not migrating south.

The City of Vineland periodically monitors its water supply system for arsenic content. The samples are taken from the distribution system, not from each individual pumping well. To date, arsenic has been undetected at the detection limit of 0.05 mg/l.

3.6 WATER BALANCE

A water balance was calculated to determine the amount of groundwater recharge in the Maurice River drainage system using rainfall and stream flow data from the Maurice River gauging station at Norma, NJ. A water balance was calculated for the water years 1981-1982, 1982-1983 and 1983-1984 and is shown in Table 3-6. Appendix K shows the plots and calculations for the water balance.

VIN
001
1048

TABLE 3-6

SUMMARY OF ESTIMATED AVERAGE WATER BALANCE

ITEM	1981-1982	1982-1983	1983-1984	AVERAGE OF 1981-1984
	INCHES/YEAR	INCHES/YEAR	INCHES/YEAR	INCHES/YEAR
<u>Water Gains</u>				
Precipitation	38.6	40.9	52.8	44.1
<u>Water Losses</u>				
Evapotranspiration	23.6	20.7	24.3	22.9 (52%)
Surface Runoff	5.5	11.0	13.1	9.9 (22%)
Groundwater Base Flow	<u>9.5</u> 38.6	<u>9.2</u> 40.9	<u>15.4</u> 52.8	11.5 (26%)

VIN 001 1049

To calculate the water balance the following procedure was followed for each water year. The mean monthly flow or discharge at the Maurice River gauging station at Norma, NJ was plotted against time. The volume of this plot is equal to total flow which in turn is made up of total base flow for that year plus the total surface runoff for that year. Therefore, to calculate the total runoff that enters the stream, the base flow is subtracted from the total flow.

The total mean flow was calculated by multiplying the average daily flow in each month by the number of days in the month and adding all of these products. The base flow was estimated by drawing an arbitrary base flow curve that mimicked the total flow curve during the water year. The base flow for each month was extrapolated from the plot and again added to give the mean total base flow. The total surface runoff that contributes to the discharge at the stream gauge station was determined by subtracting the base flow from the total flow.

The amount of precipitation in each water year was obtained from the Millville FAA Airport precipitation station. The monthly precipitation for each year was totalled, multiplied by the basin area and converted to the volume of rain in the Maurice River basin. Evapotranspiration was calculated for each water year by subtracting the total stream flow from the total rainfall.

The base flow or groundwater discharge for the drainage basin was calculated. The total mean base flow was divided by the basin area, 112 square miles. In water year 1981-1982, the groundwater discharge was 0.7 cfs/mi²; in water year 1982-1983, the groundwater discharge was 0.675 cfs/mi²; and in water year 1983-1984, the groundwater discharge was 1.14 cfs/mi².

Table 3-6 summarizes the water balance in inches for the water years, 1981-1982, 1982-1983 and 1983-1984. This table shows that approximately 52% (23 inches) of the available rainfall is lost to evapotranspiration, while 22% (10 inches) leaves as surface runoff and 26% (11 inches) recharges the groundwater. These are the average values over the three years analyzed.

In a study prepared for ViChem (Lennon, 1983) the average base flow for the drainage basin that includes the plant site was estimated to be approximately 0.7 cfs/mi². According to the Cumberland County Groundwater Resources report (Rooney, 1971), the average long-term annual precipitation in Cumberland County is about 44 inches and the average evapotranspiration is approximately 29 inches per year. These values are in general agreement with the values calculated for 1981-1984.

3.7 SUMMARY OF INVESTIGATION

Three aquifers were identified under the ViChem plant site, the upper, middle, and lower sands. The upper sand is separated from the middle sand by the banded zone. The lower sand lies below the middle sand and is characterized by a dark grey marker bed at the top. This marker bed was identified by ViChem previously as a 15 to 20 foot thick clay. In this investigation it was determined that this bed contained clay at some locations, however at other locations it was composed primarily of sand. The lower sand is pumped by ViChem's production well and by local municipal wells. ViChem's pumping test of the lower sand indicates that the lower sand may not be totally separated from the middle sand, and that leakage may take place across the dark grey marker bed at the base of the middle sand into the aquifer pumped by ViChem.

The upper sand is very homogeneous, with no vertical gradient between wells screened at the base or at the top.

The groundwater flow in the upper sand moves toward the Blackwater Branch to the north, northwest and west. The water levels in the upper sand are higher than in the Blackwater Branch, indicating that the upper sand discharges into this creek. The upper sand aquifer has a transmissivity of 110,000 gpd/ft, a coefficient of storage of 0.1 and a hydraulic conductivity of 2200 gpd/ft². The groundwater flow in the upper sand underneath the plant site averaged approximately 492,000 gpd, or 0.76 cfs. The groundwater flow velocity ranged between 1.8 to 5.5 ft/day. The separation between the upper sand and the middle sand by the banded zone has not been fully investigated. It is not known whether the middle sand discharges into the Blackwater Branch, although it has been determined that an upward gradient exists between the two. Based on the extent of contamination discussed later (Sections 4 and 5), it appears that groundwater contamination is restricted to the upper sand.

It should be noted that the transmissivity and storage coefficient estimated for the upper sand are based on a very short duration pumping test (eight hours) at a low flow rate (25 gpm). Typically, a 72-hour pumping test is used to determine these properties in an unconfined aquifer. It was determined that performing such a test was premature for the RI/FS stage of this investigation. However, such a test is recommended in the event that a groundwater pump and treat remediation scheme is chosen for arsenic-contaminated groundwater in the upper sand aquifer.

VIN 001 1051

4.0 NATURE AND EXTENT OF CONTAMINATION

4.1 SURFACE SOILS

Surface soil samples were taken from the high-and low-density sampling grids. One sample from 0 to 2 feet was taken from each surface soil sampling site. Seventy-five percent of the surface soil samples were analyzed for total arsenic, while the remainder were analyzed for HSL organics and inorganics.

The analytical results of the surface soil samples are presented in Section II of Appendix A. Table 4-1 presents a summary of the compounds detected in the soil samples and their frequency of occurrence. Figure 4-1 shows the arsenic concentrations at the sampling nodes.

Arsenic was detected in 83% (90/108) of the surface soil samples in concentrations ranging from 0.43 to 650 mg/kg (three were rejected). Twelve of the samples had arsenic concentrations greater than 50 mg/kg. Twenty-five samples had arsenic concentrations greater than 20 mg/kg.

Elevated arsenic concentrations were seen in the former chicken coop area by EW-14, along the plant road between the chicken coops and the lagoon area, in the lagoon area, and in the clearing by well cluster EW-15. These are areas where contamination was expected based on the past operating practices at the plant. The arsenic soil concentrations were either very low or undetected throughout most of the low-density sampling grid except for the clearing near EW-15. The surface soils, which were stripped from the plant area in the past, were stockpiled in this clearing.

Mercury was detected in 44% (11/25) of the samples at concentrations ranging from 0.1 to 11.3 mg/kg. These concentrations were higher than expected based on the past information available.

Descriptive statistics on the arsenic and mercury occurrences in the surface soils are shown in Table 4-2 and in Figure 4-2. These show that in both cases the majority of the samples had low concentrations, with only a few samples displaying high concentrations.

Other inorganics detected included aluminum, calcium, iron, magnesium, nickel, potassium, sodium, and zinc. All of these were found at what was considered to be normal background levels. Table 4-3 provides a listing of the normal background concentrations of metals in United States sandy soils and in New Jersey Lakewood series soils.

Organics detected include chloroform, methyl chloride, butyl benzyl phthalate, bis(2-ethylhexyl)-phthalate, 4-4-DDT and dieldrin. In general the organics were found only sporadically and at low concentrations.

TABLE 4-1

SUMMARY OF CHEMICALS DETECTED
IN SOILS

<u>SURFACE SOILS</u>						
<u>COMPOUND</u>	<u>NO. OF</u> <u>OCCUR.</u>	<u>NO. OF</u> <u>ANALYSES</u>	<u>MINIMUM</u> <u>DETECTED</u> <u>CONCEN-</u> <u>TRATION</u>	<u>MAXIMUM</u> <u>DETECTED</u> <u>CONCEN-</u> <u>TRATION</u>	<u>NO. OF</u> <u>ESTIM.</u> <u>VALUES</u>	<u>NO. OF</u> <u>REJECTED</u> <u>VALUES</u>
** Class: VOLATILES (ppb)						
Methylene chloride	1	32	5.2	5.2	1	30
Chloroform	2	32	2	6	1	4
** Class: BNA (ppb)						
Diethylphthalate	1	25	370	370	0	1
Butyl benzyl phthalate	2	25	760	840	0	1
Bis(2-ethylhexyl)phthalate	12	25	45	180	12	1
**Class: PEST/PCB (ppb)						
Dieldrin	1	25	39	39	0	3
4,4-DDT	2	25	20	39	0	3
**Class: INORGANICS (ppb)						
Aluminum	25	25	766	3260	0	0
Arsenic	90	111	0.43	650	53	3
Barium	25	25	2.3	12	25	0
Calcium	25	25	43	1150	25	0
Chromium	6	25	4	13	1	1
Copper	9	25	3	45	7	0
Iron	25	25	1230	4490	0	0
Lead	16	25	2	12	3	5
Magnesium	23	25	46	197	23	0
Manganese	25	25	4.6	35	25	0
Mercury	11	25	0.1	11.3	0	0
Nickel	7	25	8.8	26.4	5	0
Potassium	7	25	388	538.	7	0
Sodium	20	25	54	244.	20	0
Vanadium	2	25	6.6	8.4	2	0
Zinc	20	25	5.6	33.	11	2
<u>SUBSURFACE SOILS</u>						
** Class: VOLATILES (ppb)						
Methylene chloride	21	67	1	113900	7	34
Acetone	2	67	60	270	0	51
Carbon disulfide	3	67	8	45	0	C
1,1-Dichloroethene	1	67	16	16	1	C
Chloroform	5	67	1	3	5	1

VIN 001 1054

TABLE 4-1 (Cont'd)

SUMMARY OF CHEMICALS DETECTED
IN SOILS

<u>SUBSURFACE SOILS</u> <u>VOLATILES (CONT'D)</u>			MINIMUM DETECTED	MAXIMUM DETECTED	NO. OF	NO. OF
<u>COMPOUND</u>	<u>NO. OF</u>	<u>NO. OF</u>	<u>CONCEN-</u>	<u>CONCEN-</u>	<u>ESTIM.</u>	<u>REJECTED</u>
	<u>OCCUR.</u>	<u>ANALYSES</u>	<u>TRATION</u>	<u>TRATION</u>	<u>VALUES</u>	<u>VALUES</u>
2-Butanone	2	67	27000	285560	2	11
Trichloroethene	1	67	32	32	0	0
Benzene	4	67	2	52	2	0
Bromoform	2	67	1	2	2	0
4-Methyl-2-Pentanone	1	67	5	5	1	0
2-Hexanone	1	67	6	6	1	0
Tetrachloroethene	2	67	12	80	0	0
1,1,2,2-Tetrachloroethane	1	67	3	3	1	0
Toluene	10	67	5	3470	3	4
**Class: BNA (ppb)						
Benzoic acid	1	67	160	160	1	1
Diethylphthalate	2	67	60	480	2	1
Di-n-Buthylphthalate	4	67	330	560	4	21
Benzo(a)Anthracene	1	67	160	160	1	1
Bis(2-ethylhexyl)phthalate	15	67	40	1500	8	15
Chrysene	1	67	200	200	1	1
Di-n-octyl phthalate	1	67	460	460	0	1
Benzo(b)fluoranthene	1	67	550	550	0	1
**Class: PEST/PCB (ppb)						
Beta-BHC	3	65	13	17	1	1
Endosulfan I	1	65	8.2	8.2	1	1
4-4-DDE	1	65	0.18	0.18	1	1
Endrin	3	65	0.33	2.9	3	1
**Class: INORGANICS (ppm)						
Aluminum	66	67	145	5760	27	0
Antimony	2	67	35	39	0	0
Arsenic	165	328	0.581	482	57	8
Barium	32	67	1	40	32	17
Beryllium	5	67	0.2	0.2	5	0
Cadmium	4	67	0.6	1.06	4	0
Calcium	34	67	30	891	34	14
Chromium	46	67	2.4	34	22	
Cobalt	4	67	3.4	14	3	
Copper	14	67	1.8	24	10	
Iron	53	67	472	25900	0	
Lead	28	67	1.2	23	5	

VIN 001 1055

TABLE 4-1 (Cont'd)

SUMMARY OF CHEMICALS DETECTED
IN SOILS

<u>SUBSURFACE SOILS</u> <u>INORGANICS (CONT'D)</u>			MINIMUM	MAXIMUM		
<u>COMPOUND</u>	<u>NO. OF</u>	<u>NO. OF</u>	<u>DETECTED</u>	<u>DETECTED</u>	<u>NO. OF</u>	<u>NO. OF</u>
	<u>OCCUR.</u>	<u>ANALYSES</u>	<u>CONCEN-</u>	<u>CONCEN-</u>	<u>ESTIM.</u>	<u>REJECTED</u>
			<u>TRATION (ppm)</u>	<u>TRATION (ppm)</u>	<u>VALUES</u>	<u>VALUES</u>
Magnesium	11	67	49	282	11	15
Manganese	52	67	1.9	63	32	9
Mercury	7	67	0.1	1.2	0	13
Nickel	6	67	6.3	19	5	0
Potassium	9	67	104	940	8	10
Selenium	3	67	0.6	10	0	0
Silver	8	67	2.4	4.1	8	0
Sodium	13	67	44	4890	12	13
Vanadium	24	66	1.9	26	22	1
Zinc	54	62	2.8	49	21	5

BUILDING #9 SOILS

**Class: VOLATILES (ppb)

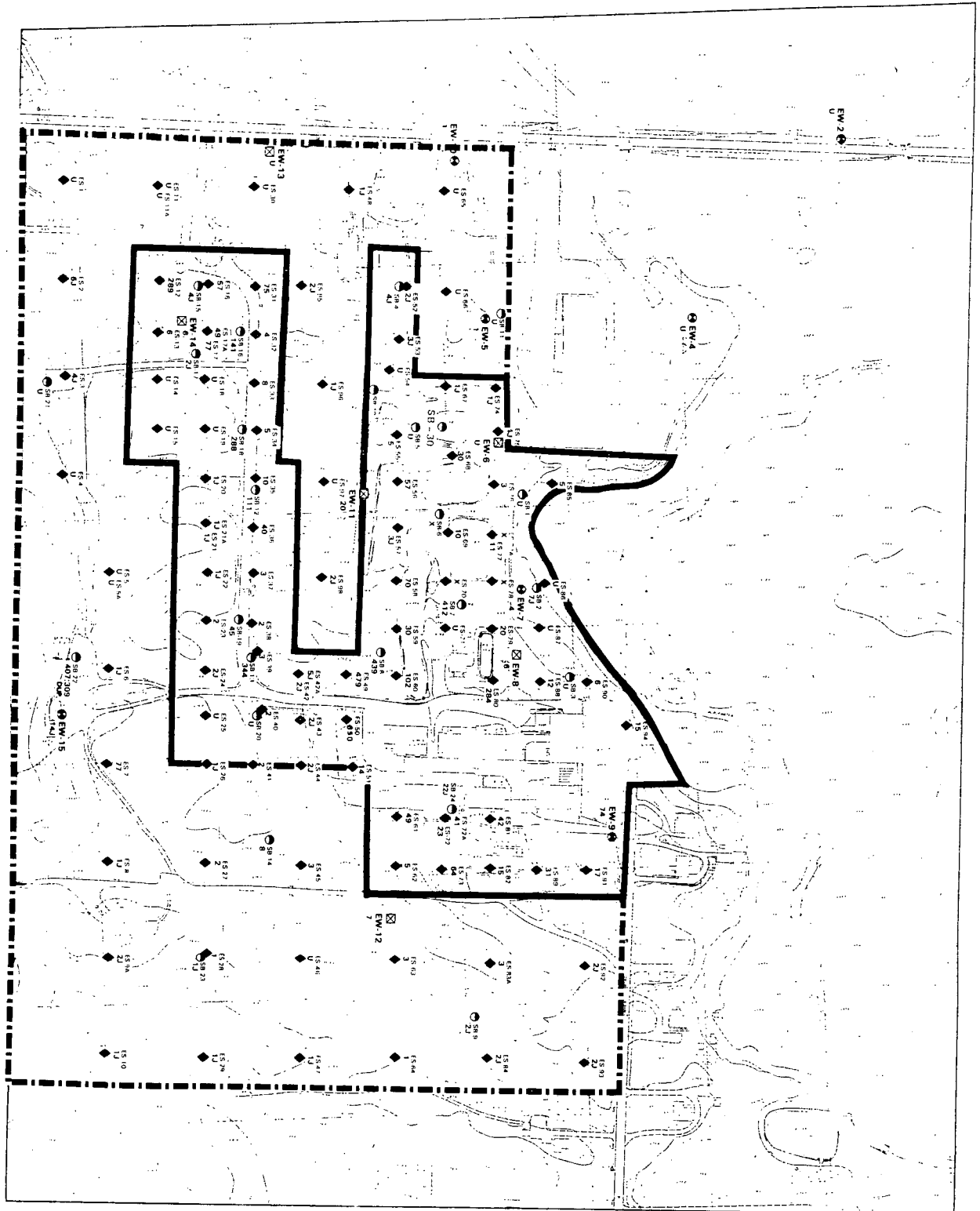
Methylene chloride	4	11	7	31	0	7
Acetone	1	11	15000	15000	0	10
Toluene	1	11	3	3	1	0

**Class: BNA (ppb)

Di-n-Butylphthalate	5	11	97	690	2	0
---------------------	---	----	----	-----	---	---

**Class: INORGANICS (ppm)

Aluminum	11	11	453	2223	11	0
Arsenic	12	26	7.50	1921	0	14
Barium	11	11	1	4	11	0
Chromium	7	11	2	5	4	0
Iron	10	11	1005	2293	0	1
Lead	1	11	3.8	3.8	0	0
Manganese	11	11	2	10	10	0
Sodium	10	11	533	2798	9	1
Vanadium	11	11	2.1	5.2	10	0
Zinc	11	11	6	48	6	0



SCALE IN FEET
0 100 200

- U - UNDETECTED
- 1 - ESTIMATED VALUE
- 2 - VALUE BETWEEN CROD AND 10L
- X - REJECTED DATA
- F - FILTERED
- ⊗ TRIPLE WELL CLUSTER (1)
- ⊕ DOUBLE WELL CLUSTER (1)
- ⊙ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (1)
- PRODUCTION WELL (1)
- ⊙ HART (1)
- ⊙ SURFACE SOIL SAMPLING LOCATIONS
- ⊙ SOIL BORING LOCATIONS
- 100 GRID
- 200 GRID



TOPOLITHIC MAP PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY SUEA INTERNATIONAL, JANUARY 1988
U.S. ENVIRONMENTAL PROTECTION AGENCY
VINLAND CHEMICAL COMPANY SITE
FIGURE 4-1
SURFACE SOIL ARSENIC CONCENTRATIONS
ERASCO SERVICES INCORPORATED

VIN 0 01 1057

VIN 001 1057

Variable: Arsenic Surface Soil

Sample size	108
Average	27.8675
Median	2.565
Mode	0.295
Geometric mean	4.06838
Variance	7487.22
Standard deviation	86.5287
Standard error	8.32623
Minimum	0.29
Maximum	650
Range	649.71
Lower quartile	1
Upper quartile	14.4
Interquartile range	13.4
Skewness	5.41995
Standardized skewness	22.9949
Kurtosis	32.347
Standardized kurtosis	68.6183

Variable: Mercury Surface Soil

Sample size	25
Average	1.0792
Median	0.05
Mode	0.05
Geometric mean	0.121682
Variance	9.25152
Standard deviation	3.04163
Standard error	0.608326
Minimum	0.05
Maximum	11.3
Range	11.25
Lower quartile	0.05
Upper quartile	0.1
Interquartile range	0.05
Skewness	3.08952
Standardized skewness	6.30646
Kurtosis	8.57679
Standardized kurtosis	8.75365

TABLE 4-2. Descriptive statistics of arsenic and mercury detected in surface soil samples. Sample size includes only acceptable analyses. For purpose of these analyses, values of undetected samples were assumed to be equal to the detection values.

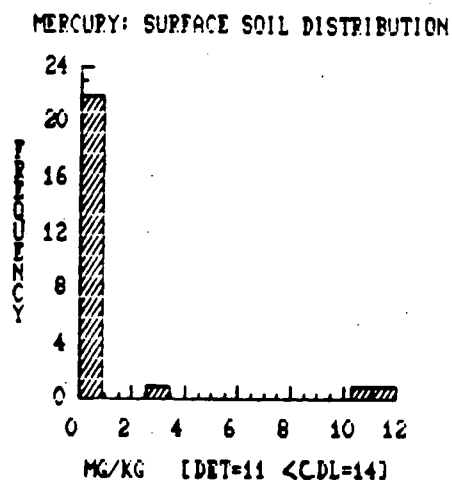
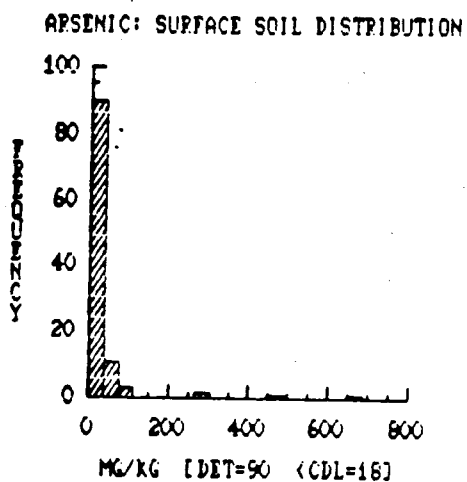


FIGURE 4-2. Distribution of arsenic and mercury concentrations in surface soil samples. The number of samples below detection limits (n) are noted as CDL = n, and DET = number of values above the detection.

TABLE 4-3

A COMPARISON OF BACKGROUND METAL CONCENTRATIONS AT THE VINELAND SITE WITH N.J. LAKEWOOD AND TYPICAL U.S. SOILS

Metal	Background Levels in Site Soils Collected via Well Borings Wells EW1, 9, 12			No. of Samples Above Detection Limit	Range of Measured Values	Range of Metals in a N. J. Lakewood type Soil ^a	Typical Range Sandy Soils in the U.S. ^b
	Mean and Std. Dev. mg/kg	Depth 5 to 120 ft Number of Samples	Estimated values in Mean				
Al	744 ± 527	8	2	8	432-1780		0.45 to 10 ^{5c}
Sb	18.4 ± 11.4	8	0	1	7.3-39		0.05-4.0 ^c
As	3.27 ± 1.77	7	1	2	1.2-5.3		0.1-30
Cr	6.15 ± 3.67	8	1	7	2.0-12	5.0-10.0	3-200
Co	6.01 ± 4.04	8	1	1	1.6-11	0.5-1.1	0.4-20
Cu	3.56 ± 1.12	8	1	2	2.0-5.8	0.5-1.1	1-70
Fe	4710 ± 3550	7	0	6	599-9995		
Pb	2.39 ± 0.87	7	1	4	1.1-3.25	10-30	10-70
Mn	6.83 ± 4.55	7	0	0	0.1-0.11		0.01-0.54
Ni	7.74 ± 4.87	8	1	2	1.3-15	11.1-13.1	5-70
Se	1.67 ± 0.87	8	0	0	0.45-3.0		0.005-3.5
Zn	10.0 ± 6.49	8	1	7	4.8-23	4.5-10.0	15-164

a. From Tedrow, J.C.F. 1986 In: Soils of New Jersey, R.E. Krieger Publishers, Melbourne, FL

b. From Kabata - Pendias, A. and H. Pendias, 1984 Trace Elements in Soils and Plants, CRC Press Inc., Boca Raton, FL

c. Values are from a range of all soil types, not just sandy soils. From Kabata-Pendias and Pendias, 1984.

4.2 SUBSURFACE SOILS

Soil borings were conducted at approximately 20% of the surface soil sampling nodes. The soils were sampled at two-foot intervals to the water table. Seventy-five percent of these samples were analyzed for total arsenic, while 25% were analyzed for HSL organics and inorganics. Soil samples were also taken from the monitoring well borings. Samples were obtained at 2-foot intervals to the water table and at 10-foot intervals thereafter, and analyzed for total arsenic. In addition, one soil sample was obtained from each well screen setting and analyzed for HSL organics and inorganics.

The analytical results of these samples are presented in Sections III and IV of Appendix A. The arsenic concentrations in the soil borings are presented in Figures 4-3 and 4-4. The arsenic concentrations in the monitoring well soil samples were presented previously in Figures 2-8a through 2-8n. Table 4-1 presents a summary of the compounds detected in the subsurface soil samples.

Only a few of the soil boring samples displayed elevated arsenic concentrations. These borings were in the lagoon area, along the plant road, in the chicken coop area by EW-14, and in the clearing by EW-15. These are the same locations where surface soil arsenic contamination was observed. In general, when contamination was observed, it was highest at the surface and decreased with depth.

The majority of the soil borings displayed low or undetected arsenic concentrations. This applies to virtually all of the low-density sampling grid borings with the exception of SB-22, which is in the clearing by EW-15. Low or undetected arsenic concentrations were also seen in the majority of the high-density grid borings, even those in the lagoon area. It appears that the arsenic soil contamination is a fairly localized phenomenon.

Figures 2-8a through 2-8n displayed the arsenic concentrations from the monitoring well soil samples. These figures show that the soils below the water table generally had very low arsenic concentrations. Well cluster EW-1, across the Blackwater Branch from the site, had undetected arsenic concentrations throughout its depth to approximately 110 feet. The same is true of cluster EW-12, known to be upgradient of the site. Cluster EW-9, also upgradient of the lagoon area, had very low arsenic concentrations below the water table but had noticeable concentrations above the water table. This may be due to the surface application of arsenic containing herbicides at this location, or to past operating practices at the plant.

VIN 1001 1961



SOIL [As] = ppm

U = UNDETECTED

| | = ESTIMATED VALUE

J = VALUE BETWEEN CRDL AND IDL

X = REJECTED DATA

▲ EXISTING MONITORING WELLS (11)

● PRODUCTION WELL (1)

■ HART (1)

◆ SURFACE SOIL SAMPLE LOCATIONS

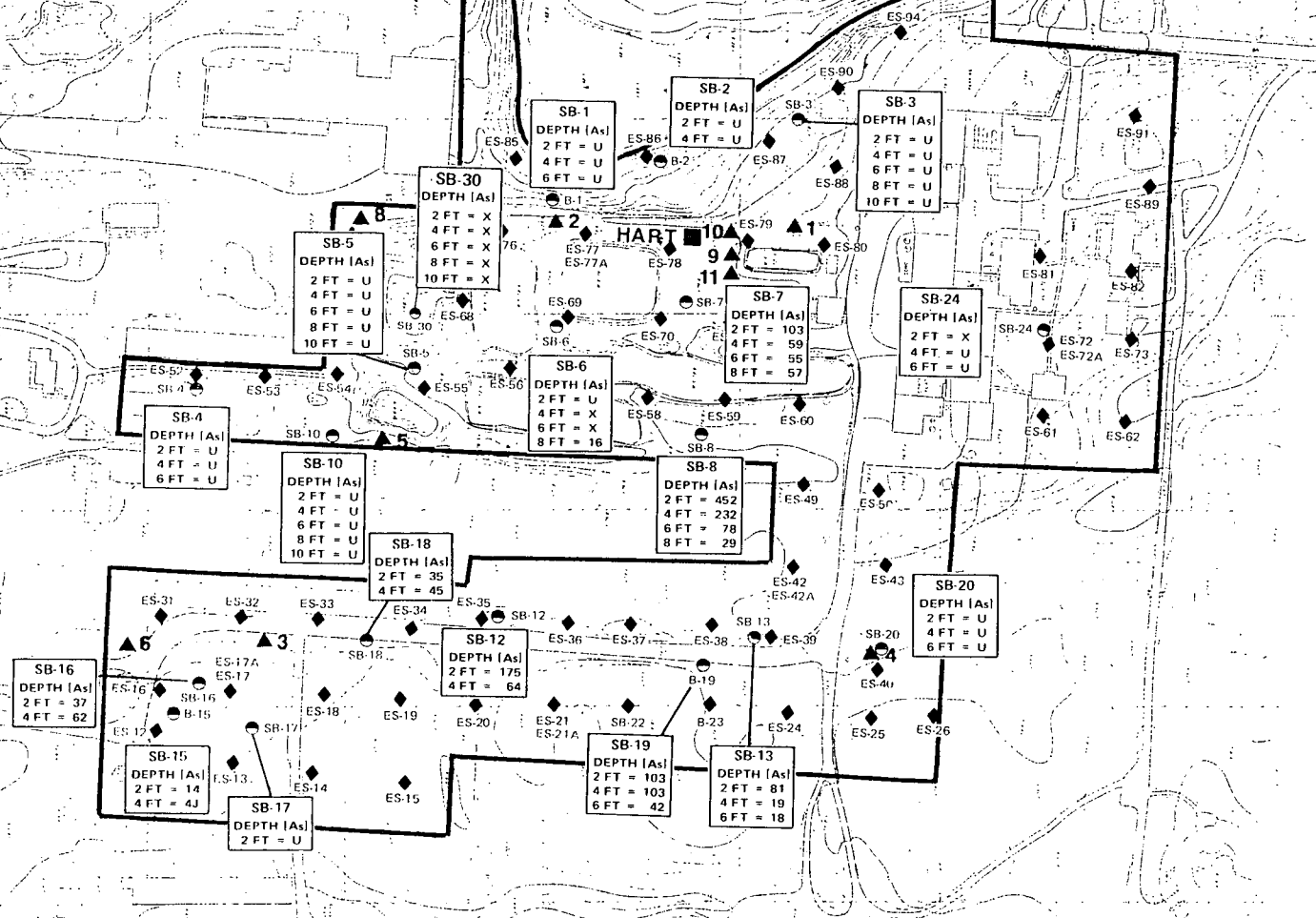
● SOIL BORING LOCATIONS

0 100 200 300

SCALE IN FEET

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF
ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

U.S. ENVIRONMENTAL PROTECTION AGENCY	VIN
VINELAND CHEMICAL COMPAN	001
FIGURE 4-3	1062
SOIL BORING ARSENIC CONCENTRATION	1 OF 2
EBASCO SERVICES INCORPO	D

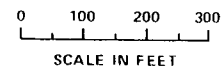


VIN 001 1063



SOIL [As] = ppm
 U = UNDETECTED
 I = ESTIMATED VALUE
 J = VALUE BETWEEN CRDL AND IDL
 X = REJECTED DATA

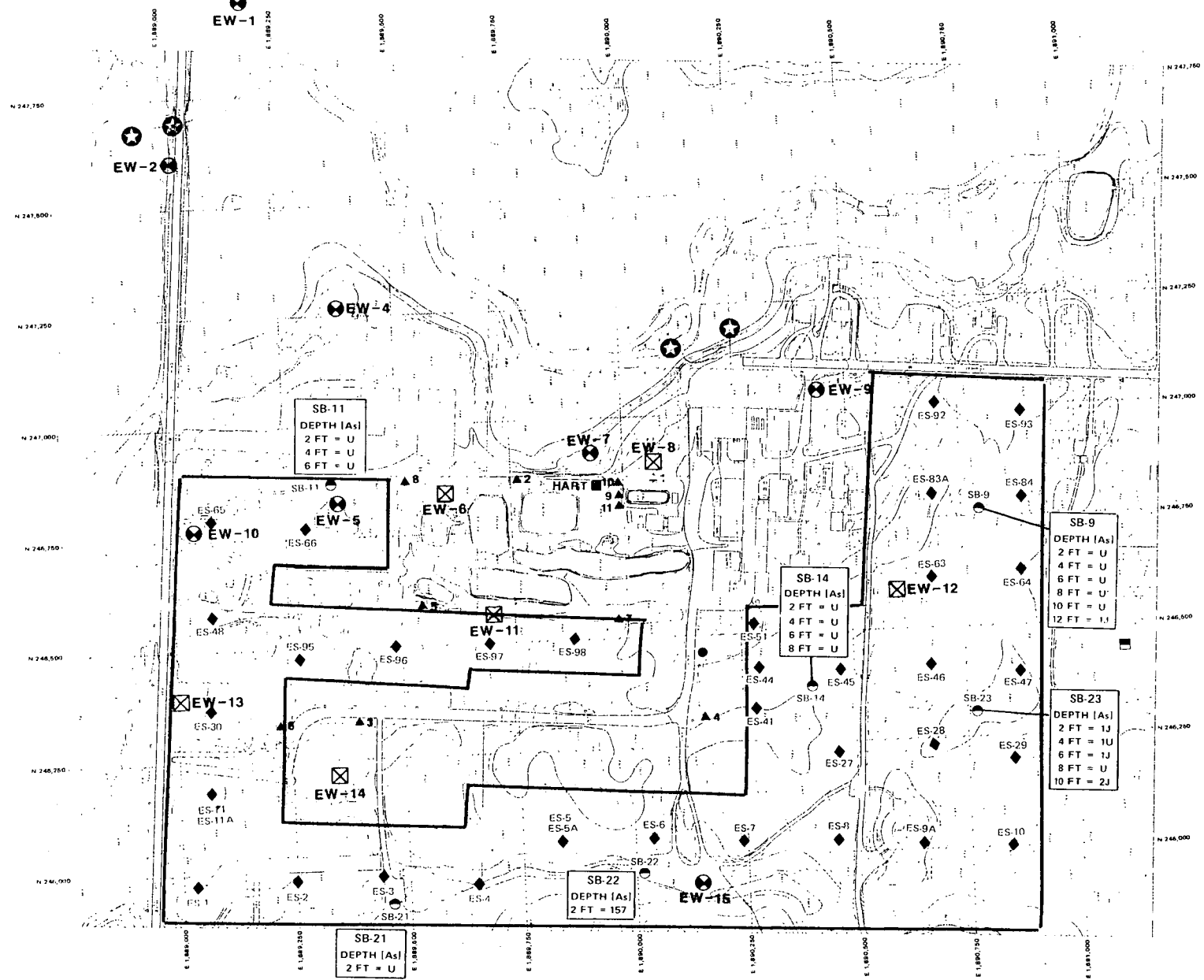
- ⊗ TRIPLE WELL CLUSTER (8)
- ⊠ DOUBLE WELL CLUSTER (6)
- ★ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART (1)
- ◆ SURFACE SOIL SAMPLE LOCATIONS
- SOIL BORING LOCATIONS



TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

U.S. ENVIRONMENTAL PROTECTION AGENCY	
VINELAND CHEMICAL COMPANY SITE	
FIGURE 4-4	
SOIL BORING ARSENIC CONCENTRATIONS	
SHEET	
EBASCO SERVICES INCORPORATE	

VIN 001 1063



When arsenic was observed in the soils below the water table, it was generally near the top of the banded zone. Elevated arsenic concentrations near the banded zone were observed in clusters EW-2, EW-4, EW-5, EW-6, EW-8, EW-11, and EW-13. In all of these instances, the arsenic concentrations below the water table but shallower than the banded zone were very low or undetected. The only cluster which displayed elevated arsenic concentrations throughout the boring to the top of the banded zone was EW-7. In general, very little arsenic was detected in the soils below the banded zone, with only isolated hits seen in cluster EW-7.

Table 4-1 displays the frequency of occurrence and maximum and minimum concentrations of compounds detected in the subsurface soil samples. Several volatile organics were detected frequently and/or at high concentrations. Methylene chloride was detected in 21/33 samples and rejected in an additional 34 samples. Methylene chloride was rejected in 26/68 of the field and trip blanks and was found in concentrations in blanks up to 1000 ug/l. Although methylene chloride was detected at high concentrations (up to 113,900 ug/kg) this is probably due to field and/or trip contamination. The compound 2-butanone was detected in 13 out of 56 samples, but 11 of the detections were rejected. In the two cases where the compound was not rejected, the concentrations were high and were flagged as estimated (27,000 ug/kg at EW-2D at 100 feet and 285,560 ug/kg at EW-9M at 69 feet). Therefore all of the 2-butanone detections were considered suspicious, particularly since this is a common laboratory contaminant. Toluene was detected in 10/63 samples at concentrations ranging from 5 to 3470 ug/kg. Toluene is a common laboratory contaminant, as are methylene chloride and 2-butanone. Therefore none of these compounds were considered in detail.

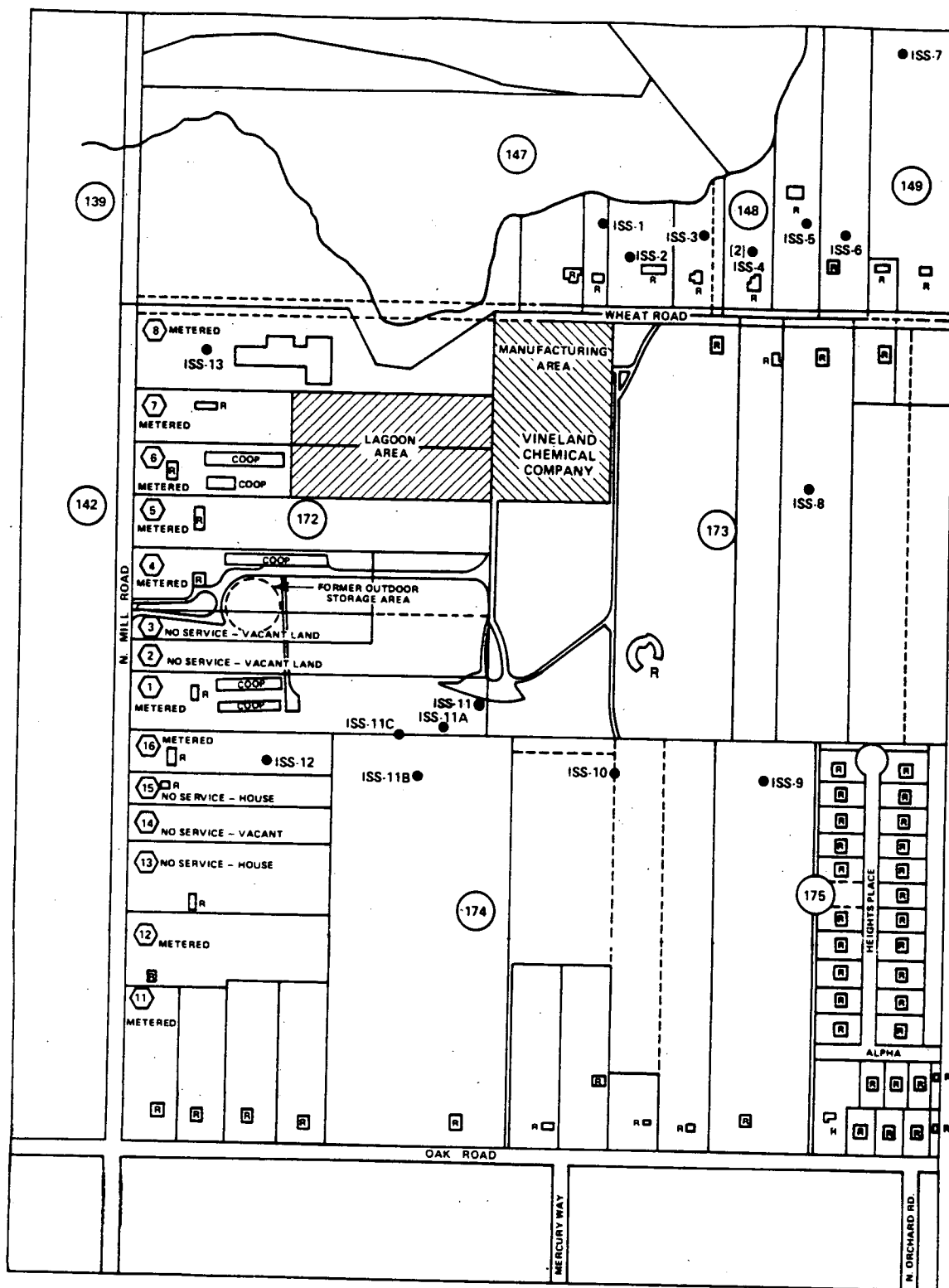
Most semivolatiles and pesticides/PCBs were detected infrequently at low concentrations with the exception of bis(2-ethylhexyl)phthalate (BEHP). BEHP was detected in 29% (15/51) of the subsurface soil samples at concentrations ranging from 40 to 1500 ug/kg. BEHP is a common laboratory contaminant, and is commonly observed at hazardous waste sites.

4.3 OFF-SITE SOILS

Soils were sampled from 13 locations surrounding the plant site. The locations are shown in Figure 4-5 with the results presented in Table 4-4.

The samples were taken to address the possibility of windblown soil contamination. Some of the samples were taken in the backyards of certain residents, while others were obtained in wooded areas adjacent to the plant.

The results showed that there were generally low arsenic concentrations in the off-site soils. The exception to this was sample ISS-11, which had a concentration of 78 mg/kg. As shown in Figure 4-5, this sample was taken close to the clearing by well cluster EW-15, where soils stripped from the manufacturing area were previously dumped.



LEGEND:

- 172 BLOCK NUMBER
- SOIL SAMPLING LOCATIONS
- R RESIDENCES
- 172 LOT NUMBER



0 200 400 600 800
SCALE IN FEET

BASE MAP PREPARED BY CITY ENGINEER, WILLIAM G. AUSTIN, CITY OF VINELAND, OCTOBER 1971.

U.S. ENVIRONMENTAL PROTECTION AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 4-5

RESIDENTIAL SOIL SAMPLING LOCATIONS AND WATER SUPPLY ALONG N. MILL ROAD

EBASCO SERVICES INCORPORATED

VIN 001 1065

TABLE 4-4

RESIDENTIAL SURFACE SOIL SAMPLES
ARSENIC CONCENTRATIONS

<u>SAMPLE ID</u>	<u>CLP SAMPLE ID</u>	<u>DATE SAMPLED</u>	<u>ARSENIC (MG/KG)</u>
ISS-1	3097B-150	7/10/87	2.2
ISS-2	3097B-151	7/10/87	0.9 U
ISS-3	3097B-152	7/10/87	1.4 J
ISS-4	3097B-153	7/10/87	1.8 J
ISS-5	3097B-154	7/10/87	12.0
ISS-6	3097B-155	7/10/87	2.5
ISS-7	3097B-156	7/10/87	2.2 J
ISS-8	3097B-157	7/10/87	2.1 J
ISS-9	3097B-158	7/10/87	1.3 J
ISS-10	3097B-159	7/10/87	0.9 J
ISS-11	3097B-160	7/10/87	78.0
ISS-11A	4288B-056	11/17/88	1.4 J
ISS-11B	4288B-057	11/17/88	0.73 J
ISS-11C	4288B-058	11/17/88	0.72 J
ISS-12	3097B-161	7/10/87	7.1
ISS-13	3097B-162	7/10/87	0.8 U
ISS-13 DUP	3097B-163	7/10/87	1.2 J

EXPLANATION OF CODES

J - ESTIMATED VALUE
 B - COMPOUND FOUND IN BLANK
 - DETECTED AT CONCENTRATION SHOWN
 U - UNDETECTED AT GIVEN INSTRUMENT DETECTION LIMIT
 R - NOT REQUIRED FOR ANALYSIS
 X - REJECTED VALUE

Because of the high concentration at ISS-11, additional samples were obtained in November 1988. These samples are shown as ISS-11A, ISS-11B, and ISS-11C in Figure 4-5. They were taken farther away from the soil dump area in undeveloped woodlands. These samples had very low arsenic concentrations.

The off-site soil data show that there has been very little to no off-site soil contaminant migration. This is consistent with the data from the site, where elevated arsenic concentrations were seen only in areas of known past contamination or where arsenic was applied directly to the soil surface.

4.4 GROUNDWATER

Groundwater samples were obtained from the 36 monitoring wells installed by Ebasco, 11 existing ViChem monitoring wells, the plant's production well, and the deep monitoring well installed by Hart in the lagoon area. Two rounds of groundwater samples were obtained. All samples were analyzed for dissolved arsenic, HSL inorganics (unfiltered), HSL volatiles, and pesticides/PCBs. In addition, 25% of the groundwater samples were analyzed for acid base/neutral extractable organics. The analytical results for all of these samples are presented in Section V of Appendix A. Table 4-5 displays the frequency of occurrence, and the maximum and minimum values for all of the compounds detected.

The principal contaminant in the groundwater is arsenic. Other contaminants included cadmium, lead and trichloroethene. Table 4-6 gives statistical information on these parameters, while Figure 4-6 presents frequency of occurrence diagrams for them.

Arsenic was found primarily in the upper sand. Concentrations ranged from undetected at upgradient wells EW-9S, EW-12S, and EW-1, across the Blackwater Branch from the site, to over 350,000 ug/l in the medium well in the EW-4 cluster (EW-4M). Very little arsenic was seen in the deep wells Ebasco installed at the base of the middle sand or in the ViChem production well, the Hart well, or EW-5D, all screened in the lower sand.

Figure 4-7 displays the average arsenic concentrations in the shallow wells from the two rounds of groundwater samples. Included in this figure are all of the shallow wells installed by Ebasco and the ViChem monitoring wells. This figure shows three arsenic maxima. One of the maxima is in the northern portion of the lagoon area near the lined concrete lagoon and wells MW-9, MW-10, MW-11, and EW-8. Shallow arsenic concentrations here are as high as 6,000 ug/l. The second maximum is near the chicken coops at the southwestern end of the property, where concentrations are as high as 5,000 ug/l. The third area is the clearing by EW-15. Concentrations here are much lower than in the other areas, approximately 260 ug/l. By contouring the data it appears that the contamination is spreading to the north and northwest.

TABLE 4-5

SUMMARY OF CHEMICALS DETECTED
IN GROUNDWATER

<u>SHALLOW GROUNDWATER</u>			MINIMUM	MAXIMUM		
<u>COMPOUND</u>	<u>NO.</u> <u>OF</u> <u>OCCUR.</u>	<u>NO.</u> <u>OF</u> <u>ANALYSES</u>	<u>DETECTED</u> <u>CONCEN-</u> <u>TRATION</u> <u>(ppb)</u>	<u>DETECTED</u> <u>CONCEN-</u> <u>TRATION</u> <u>(ppb)</u>	<u>NO.</u> <u>OF</u> <u>EST.</u> <u>VALUES</u>	<u>NO.</u> <u>OF</u> <u>REJECTED</u> <u>VALUES</u>
**CLASS: VOLATILES						
METHYLENE CHLORIDE	1	59	10	10	0	18
1,1-DICHLOROETHANE	1	59	2.7	2.7	1	3
CHLOROFORM	1	59	1	1	1	7
1,1,1-TRICHLOROETHANE	9	59	1.4	17	7	3
TRANS-1,3-DICHLORO- PROPENE	1	59	43	43	0	2
TRICHLOROETHENE	11	59	1.3	1600	1	5
BROMOFORM	1	59	2.2	2.2	1	2
TETRACHLOROETHENE	4	59	0.5	4	4	5
1,1,2,2-TETRACHLORO- ETHANE	1	59	9.3	9.3	0	2
ETHYLBENZENE	2	59	0.5	0.6	1	3
TOTAL XYLENES	4	59	1.8	3.4	3	2
**CLASS: BNA						
DIETHYLPHTHALATE	1	14	4	4	1	6
DI-n-BUTYLPHTHALATE	1	14	0.4	0.4	0	0
BIS[2-ETHYLHEXYL] PHTHALATE	5	14	1.7	5.8	2	5
DI-n-OCTYL PHTHALATE	1	14	2	2	1	0
**CLASS: PEST/PCB						
BETA-BHC	1	56	0.09	0.09	0	6
GAMMA-BHC	7	56	3	13	0	6
HEPATCHLOR	1	56	12	12	0	8
ENDOSULFAN I	1	56	0.557	0.557	0	6
4-4-DDT	1	56	0.23	0.23	0	9
ENDRIN KETONE	3	56	0.03	0.21	0	10
**CLASS: INORGANICS (ppm)						
ALUMINUM	53	60	33	334000	16	1
ANTIMONY	13	60	58	10400	3	18
ARSENIC	93	114	2.100	26900	11	9
BARIUM	34	60	3	26900	33	0
BERYLLIUM	1	60	4	4	1	0

TABLE 4-5 (Cont'd)

SUMMARY OF CHEMICALS DETECTED
IN GROUNDWATER

<u>SHALLOW GROUNDWATER</u>						
<u>COMPOUND</u>	<u>NO.</u> <u>OF</u> <u>OCCUR.</u>	<u>NO.</u> <u>OF</u> <u>ANALYSES</u>	<u>MINIMUM</u> <u>DETECTED</u> <u>CONCEN-</u> <u>TRATION</u> <u>(ppb)</u>	<u>MAXIMUM</u> <u>DETECTED</u> <u>CONCEN-</u> <u>TRATION</u> <u>(ppb)</u>	<u>NO.</u> <u>OF</u> <u>EST.</u> <u>VALUES</u>	<u>NO.</u> <u>OF</u> <u>REJECTED</u> <u>VALUES</u>
CADMIUM	32	60	4	457	8	4
CALCIUM	59	60	605	11700	52	0
CHROMIUM	4	60	14.4	399	1	0
COBALT	4	60	9.4	90	3	0
COPPER	22	60	19.7	3050	12	0
IRON	56	60	6.02	430000	8	3
LEAD	9	60	2.9	3010	6	25
MAGNESIUM	59	60	180	8450	57	0
MANGANESE	60	60	21	1710	23	0
MERCURY	14	60	0.25	13.2	1	3
NICKEL	18	60	7.4	368	15	22
POTASSIUM	48	60	532	8140	43	0
SELENIUM	3	60	1.9	376	2	9
SILVER	1	60	51	51	0	0
SODIUM	58	60	1140	58000	12	1
VANADIUM	2	60	12.6	567	1	0
ZINC	49	60	19.3	686	19	5

INTERMEDIATE GROUNDWATER

<u>COMPOUND</u>	<u>NO.</u> <u>OF</u> <u>OCCUR.</u>	<u>NO.</u> <u>OF</u> <u>ANALYSES</u>	<u>MINIMUM</u> <u>DETECTED</u> <u>CONCEN-</u> <u>TRATION</u> <u>(ppb)</u>	<u>MAXIMUM</u> <u>DETECTED</u> <u>CONCEN-</u> <u>TRATION</u> <u>(ppb)</u>	<u>NO.</u> <u>OF</u> <u>EST.</u> <u>VALUES</u>	<u>NO.</u> <u>OF</u> <u>REJECTED</u> <u>VALUES</u>
**CLASS: VOLATILES						
ACETONE	7	31	170	180	0	23
CARBON DISULFIDE	27	31	17	17	0	3
1,1-DICHLOROETHANE	28	31	2.4	2.4	2	2
CHLOROFORM	27	31	1	6.7	5	3
1,1,1-TRICHLOROETHANE	28	31	2	3	7	2
CARBON TETRACHLORIDE	29	31	2	2	1	1
TRICHLOROETHENE	30	31	1	260	6	0
BENZENE	24	31	1.3	8	3	5
TETRACHLOROETHENE	28	31	0.2	0.2	1	1

**CLASS: BNA

TABLE 4-5 (Cont'd)

SUMMARY OF CHEMICALS DETECTED
INTERMEDIATE GROUNDWATER

<u>COMPOUND</u>	<u>NO. OF OCCUR.</u>	<u>NO. OF ANALYSES</u>	<u>MINIMUM DETECTED CONCEN- TRATION (ppb)</u>	<u>MAXIMUM DETECTED CONCEN- TRATION (ppb)</u>	<u>NO. OF EST. VALUES</u>	<u>NO. OF REJECTED VALUES</u>
DIETHYLPHTHALATE	1	12	2	2	1	0
IDENO[1,2,3-CD]PYRENE	1	12	20	20	0	0
**CLASS: PEST/PCB						
GAMMA-BHC	1	27	6	6	1	3
HEPATCHLOR	1	27	0.584	0.584	0	2
ENDOSULFAN I	2	27	0.765	1.857	1	0
4-4-DDD	1	27	0.038	0.038	1	1
4-4-DDT	2	27	0.53	1.06	1	3
ENDRIN KETONE	5	27	0.02	0.37	1	1
AROCHLOR 1254	2	27	2.1	17	0	0

****CLASS: INORGANICS (ppm)**

ALUMINUM	21	31	94	5070	11	1
ANTIMONY	1	31	62	62	0	6
ARSENIC	39	62	4.4	394000	8	10
BARIUM	15	31	9.3	155	15	0
CADMIUM	10	31	6.4	9580	0	3
CALCIUM	31	31	1100	9950	23	0
CHROMIUM	4	31	92	14.8	2	0
COBALT	2	31	16	18	2	0
COPPER	12	31	17	82	10	0
IRON	26	31	388	38600	9	5
LEAD	9	31	3	110	1	10
MAGNESIUM	31	31	438	3400	31	0
MANGANESE	29	31	22	986	12	2
MERCURY	0	31	0.2	0.2	0	2
NICKEL	3	31	14	37	3	21
POTASSIUM	29	31	534	14000	21	0
SELENIUM	5	31	1.5	13	3	8
SILVER	1	31	60	60	0	0
SODIUM	31	31	2620	432000	12	0
ZINC	27	31	19.1	72	8	0

DEEP GROUNDWATER**** CLASS: VOLATILES**

ACETONE	5	19	24	24	0	12
CHLOROFORM	16	19	2	2	1	1
CARBON TETRACHLORIDE	17	19	1.9	1.9	1	0

TABLE 4-5 (Cont'd)

SUMMARY OF CHEMICALS DETECTED
IN GROUNDWATER

<u>COMPOUND</u>	<u>NO.</u> <u>OF</u> <u>OCCUR.</u>	<u>NO.</u> <u>OF</u> <u>ANALYSES</u>	<u>MINIMUM</u> <u>DETECTED</u> <u>CONCEN-</u> <u>TRATION</u> <u>(ppb)</u>	<u>MAXIMUM</u> <u>DETECTED</u> <u>CONCEN-</u> <u>TRATION</u> <u>(ppb)</u>	<u>NO.</u> <u>OF</u> <u>EST.</u> <u>VALUES</u>	<u>NO.</u> <u>OF</u> <u>REJECTED</u> <u>VALUES</u>
<u>DEEP GROUNDWATER</u>						
** CLASS: BNA						
BIS(2-ETHYLHEXYL) PHTHALATE	3	19	2.4	2.4	1	3
** CLASS: PEST PCB						
4-4-DDT	10	19	0.38	0.38	0	5
ENDRIN KETONE	10	19	0.12	0.28	0	5
** CLASS: INORGANICS						
ALUMINUM	15	19	495	4580	3	2
ANTIMONY	15	19	330	330	0	2
ARSENIC	27	38	4	34	6	7
BARIUM	17	19	26	280	12	0
CADMIUM	16	19	4.9	4.9	1	1
CALCIUM	17	19	708	57900	12	0
CHROMIUM	17	19	14	36.4	1	0
COPPER	17	19	52.6	82.9	3	0
IRON	10	19	470	4970	3	7
LEAD	12	19	3.6	99.3	4	5
MAGNESIUM	17	19	180	3860	16	0
MANGANESE	16	19	11	93.8	8	1
MERCURY	16	19	0.26	0.26	1	1
NICKEL	8	19	35	67	2	9
POTASSIUM	17	19	605	52700	10	0
SILVER	17	19	7	7	1	0
SODIUM	17	19	4540	236000	6	0
ZINC	17	19	21	78.1	3	0

Variable: Arsenic Groundwater

Sample size	153
Average	10200.1
Median	394
Mode	2
Geometric mean	280.756
Variance	2.65223E9
Standard deviation	51499.8
Standard error	4163.52
Minimum	0.75
Maximum	394000
Range	393999
Lower quartile	32.1
Upper quartile	2790
Interquartile range	2757.9
Skewness	6.42863
Standardized skewness	32.463
Kurtosis	41.4315
Standardized kurtosis	104.61

Variable: Trichloroethene Groundwater

Sample size	79
Average	31.6734
Median	2.5
Mode	2.5
Geometric mean	3.84024
Variance	33350.4
Standard deviation	182.621
Standard error	20.5465
Minimum	1
Maximum	1600
Range	1599
Lower quartile	2.5
Upper quartile	2.5
Interquartile range	0
Skewness	8.36236
Standardized skewness	30.3436
Kurtosis	72.2352
Standardized kurtosis	131.056

Variable: Lead Groundwater

Sample size	54
Average	64.0343
Median	1.45
Mode	1.45
Geometric mean	3.57929
Variance	167182
Standard deviation	408.879
Standard error	55.6414
Minimum	1.45
Maximum	3010
Range	3008.55
Lower quartile	1.45
Upper quartile	4.5
Interquartile range	3.05
Skewness	7.32536
Standardized skewness	21.9761
Kurtosis	53.7656
Standardized kurtosis	80.6484

Variable: Cadmium Groundwater

Sample size	82
Average	278.578
Median	4.3
Mode	2
Geometric mean	8.85473
Variance	2.16673E6
Standard deviation	1471.98
Standard error	162.553
Minimum	2
Maximum	9580
Range	9578
Lower quartile	2
Upper quartile	17
Interquartile range	15
Skewness	6.21857
Standardized skewness	22.9891
Kurtosis	37.8597
Standardized kurtosis	69.9807

TABLE 4-6. Descriptive statistics of arsenic, trichloroethene, lead, and cadmium detected in groundwater (shallow and intermediate depth wells). Sample size includes only acceptable analyses. For the purposes of these analyses, values of undetected samples were assumed to equal to half the detection values.

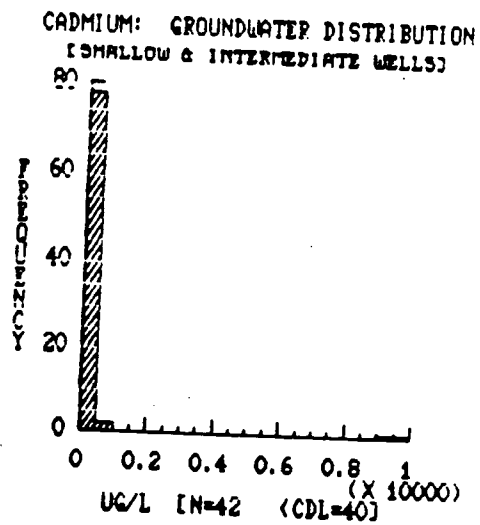
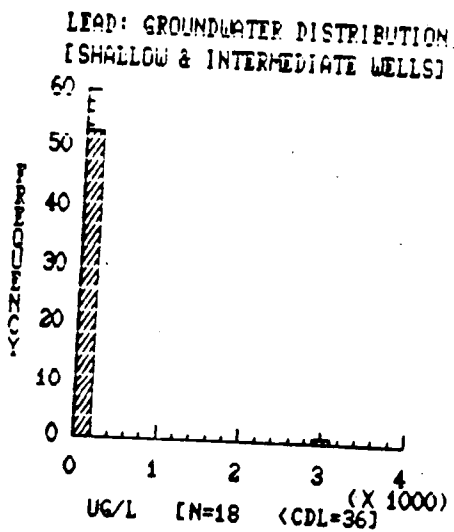
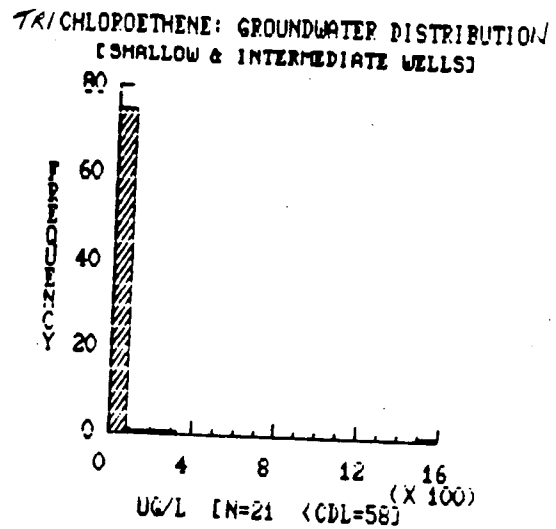
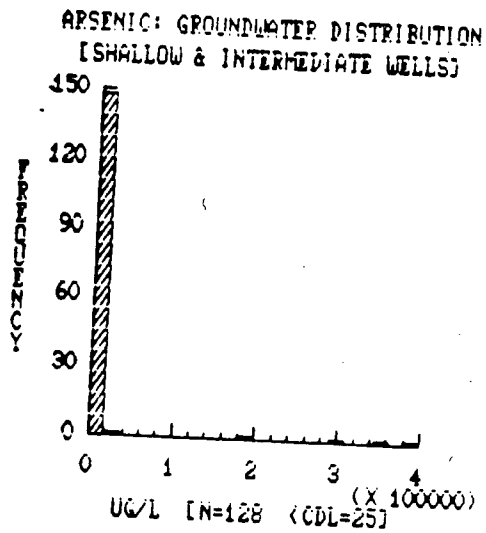
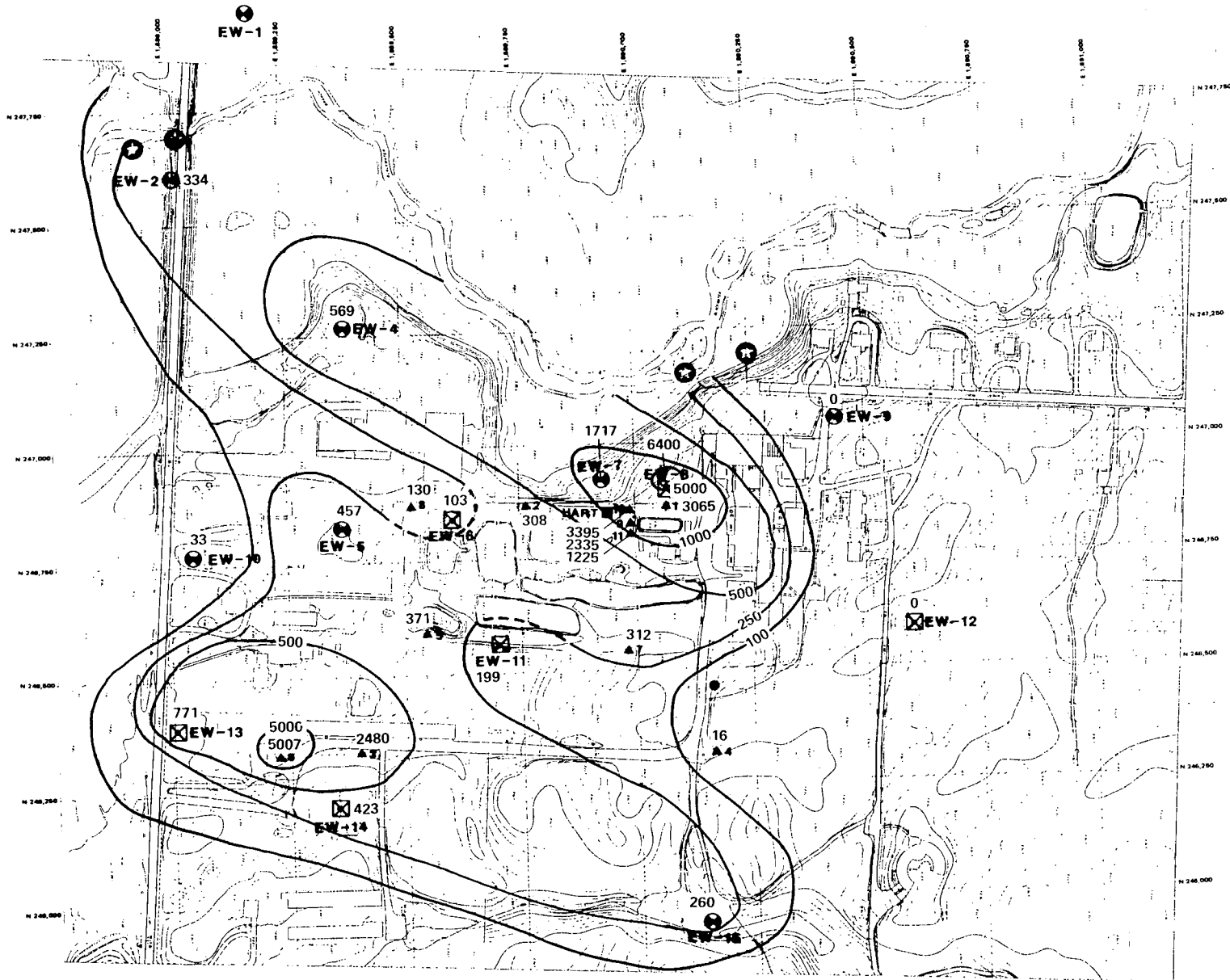


FIGURE 4-6. Distribution of arsenic, trichloroethene, lead, and mercury in groundwater (shallow and intermediate depth wells). The number of samples below detection limits(n) are noted as CDL = n, and N = the number of values above the detection limit.

VIN 001 1074



TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 4-7
AVERAGE ARSENIC CONCENTRATION SHALLOW WELLS
EBASCO SERVICES INCORPORATE

VIN 001 1074

Figure 4-8 shows the average arsenic concentrations in the medium wells installed by Ebasco. While this figure shows that the estimated plume is smaller, the concentrations are higher in some places. For example, the concentration in the medium well in the EW-4 cluster is over 300,000 ug/l while the concentration in the medium well in the EW-7 cluster is almost 15,000 ug/l. The contamination in the medium wells is observed north and northwest of the plant.

Figure 4-9 shows the average arsenic concentrations in the deep wells. These wells are all installed below the banded zone at the base of the middle sand. The arsenic concentrations are very low to undetected. The highest average concentration is at the deep well in the EW-15 cluster, an estimated 17 ug/l.

These figures combine to show a significant plume of arsenic contamination in the shallow groundwater. The upper sand aquifer has arsenic contamination to its base at the banded zone. Contamination is seen at the top of the upper sand from the shallow wells and at the base of the upper sand from the medium wells. There is very little arsenic contamination below the banded zone in any of the wells in the middle or lower sands.

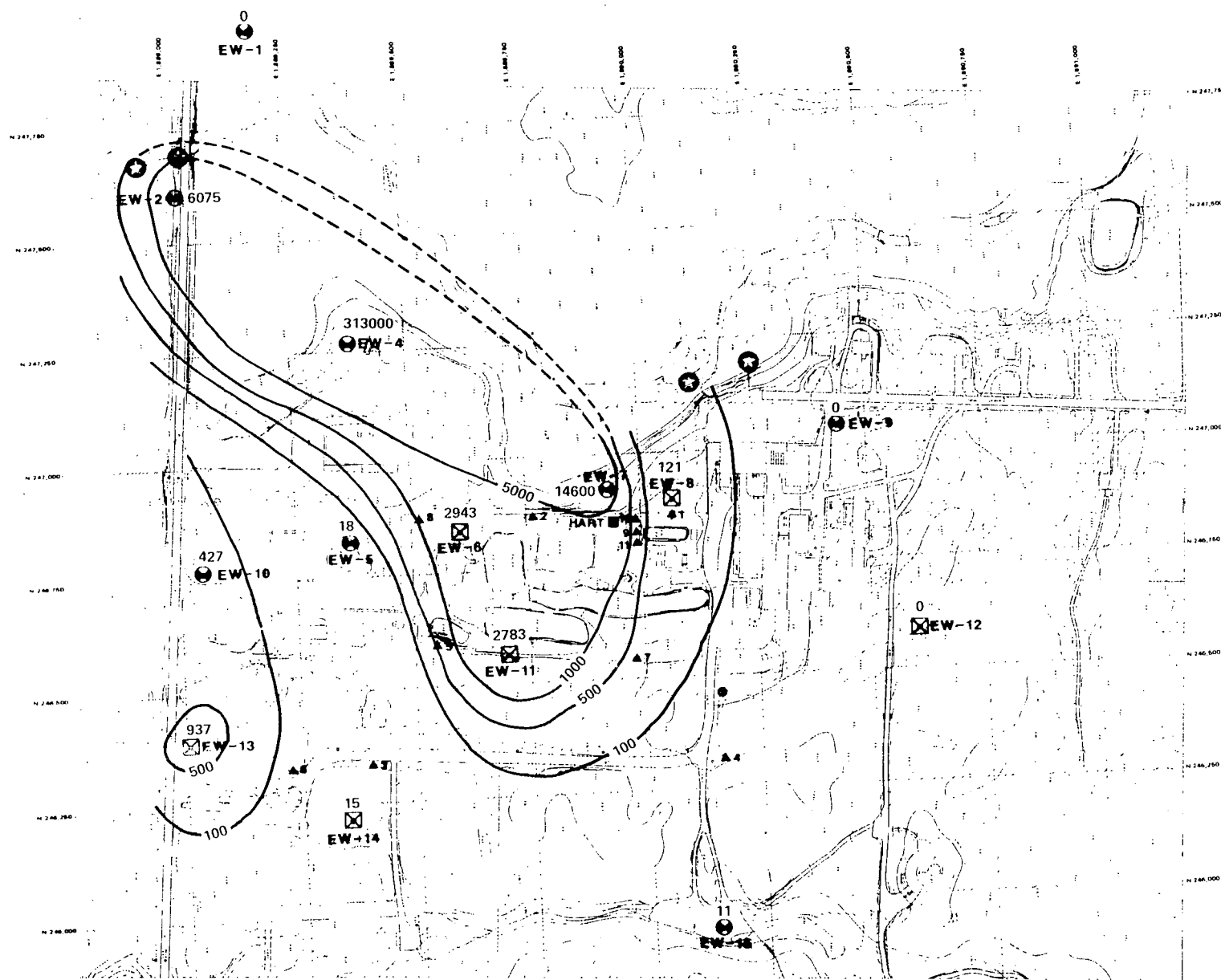
Wells in the EW-1, EW-9, and EW-12 clusters all display undetected arsenic concentrations. Clusters EW-9 and EW-12 are known to be upgradient of the lagoon area. Cluster EW-1 is in the direction of the contaminant plume, but it is across the Blackwater Branch from the site. Cluster EW-2 is in approximately the same line from the lagoon area as EW-1, but EW-2 is on the same side of the Blackwater Branch as the site. EW-2 displays significant contamination at the top and base of the upper sand. There is an upward hydraulic gradient between the upper sand from both EW-1 and EW-2. All of the above are interpreted to indicate that groundwater contamination in the upper sand is probably not crossing underneath the Blackwater Branch, and probably instead discharges into this stream.

The cadmium concentrations in the shallow and medium wells are presented in Figures 4-10 and 4-11. These figures show that there is significant cadmium contamination in the groundwater in the upper sand. High concentrations are observed north of the lagoons, in the old chicken coop area by EW-14, and in the medium well in the EW-4 cluster. The cadmium plume has the same basic configuration as the arsenic plume.

While elevated cadmium concentrations are observed in the shallow groundwater, no cadmium was detected in any of the soil samples. It is known, however, that ViChem previously produced a cadmium-based herbicide, ViCad.

Other contaminants found frequently in the groundwater include lead, trichloroethene, and various pesticides. Figures 4-12 and 4-13 show the trichloroethene and pesticides concentrations at various locations.

VIN 001 1076



GROUNDWATER [AS] : ppb
 U = UNDETECTED
 | | = ESTIMATED VALUE
 J = VALUE BETWEEN CRDL AND IDL
 ☼ TRIPLE WELL CLUSTER (8)
 ⊠ DOUBLE WELL CLUSTER (6)
 ☼ STREAM GAUGE STATIONS
 ▲ EXISTING MONITORING WELLS (11)
 ● PRODUCTION WELL (1)
 ■ HART (1)
 LL LINED LAGOON
 UL UNLINED LAGOON

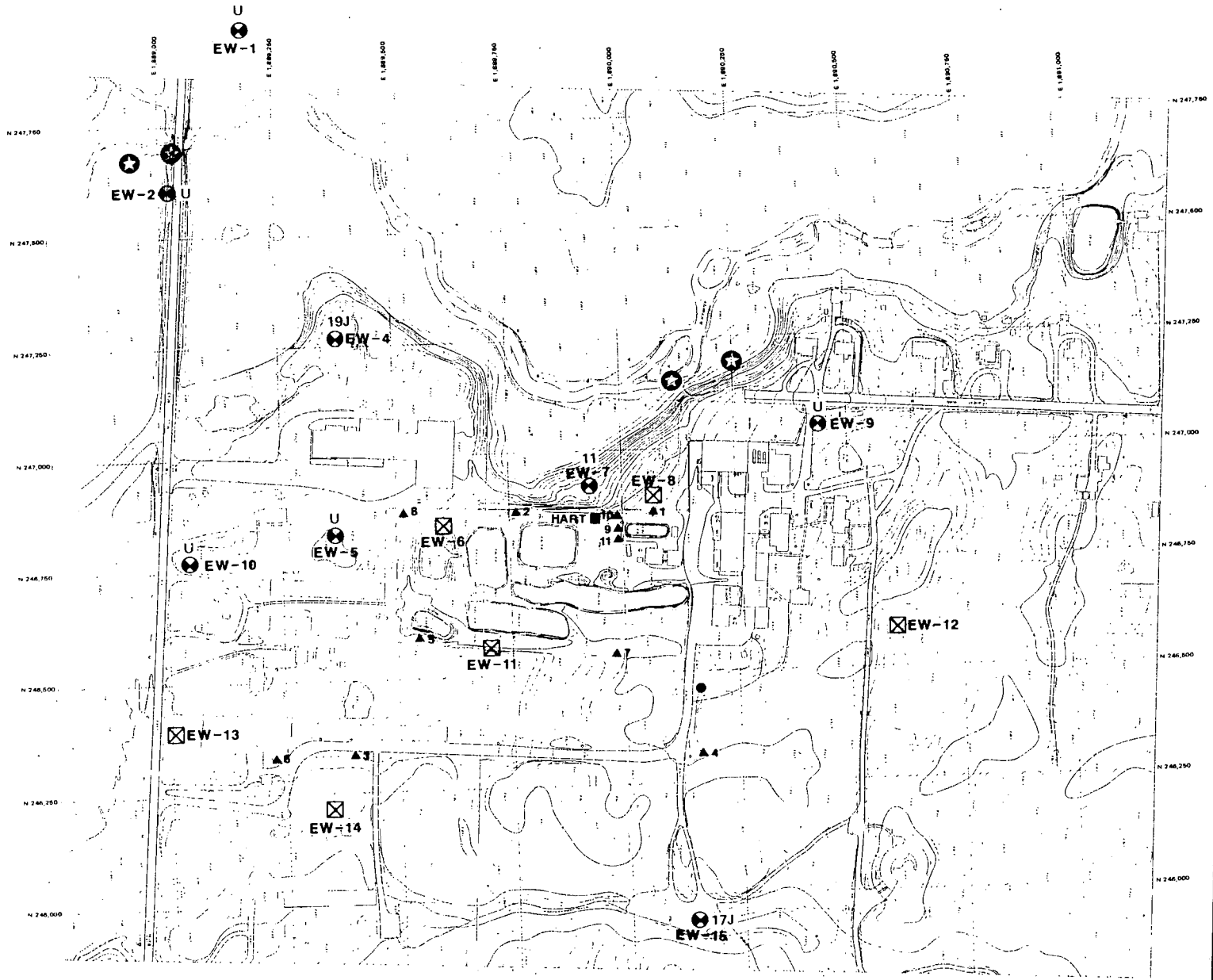
0 100 200 300
 SCALE IN FEET

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

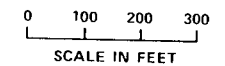
U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 4-8
AVERAGE ARSENIC CONCENTRATION MEDIUM WELLS
EBASCO SERVICES INCORPORATE

VIN 001 1076

VIN 001 1077



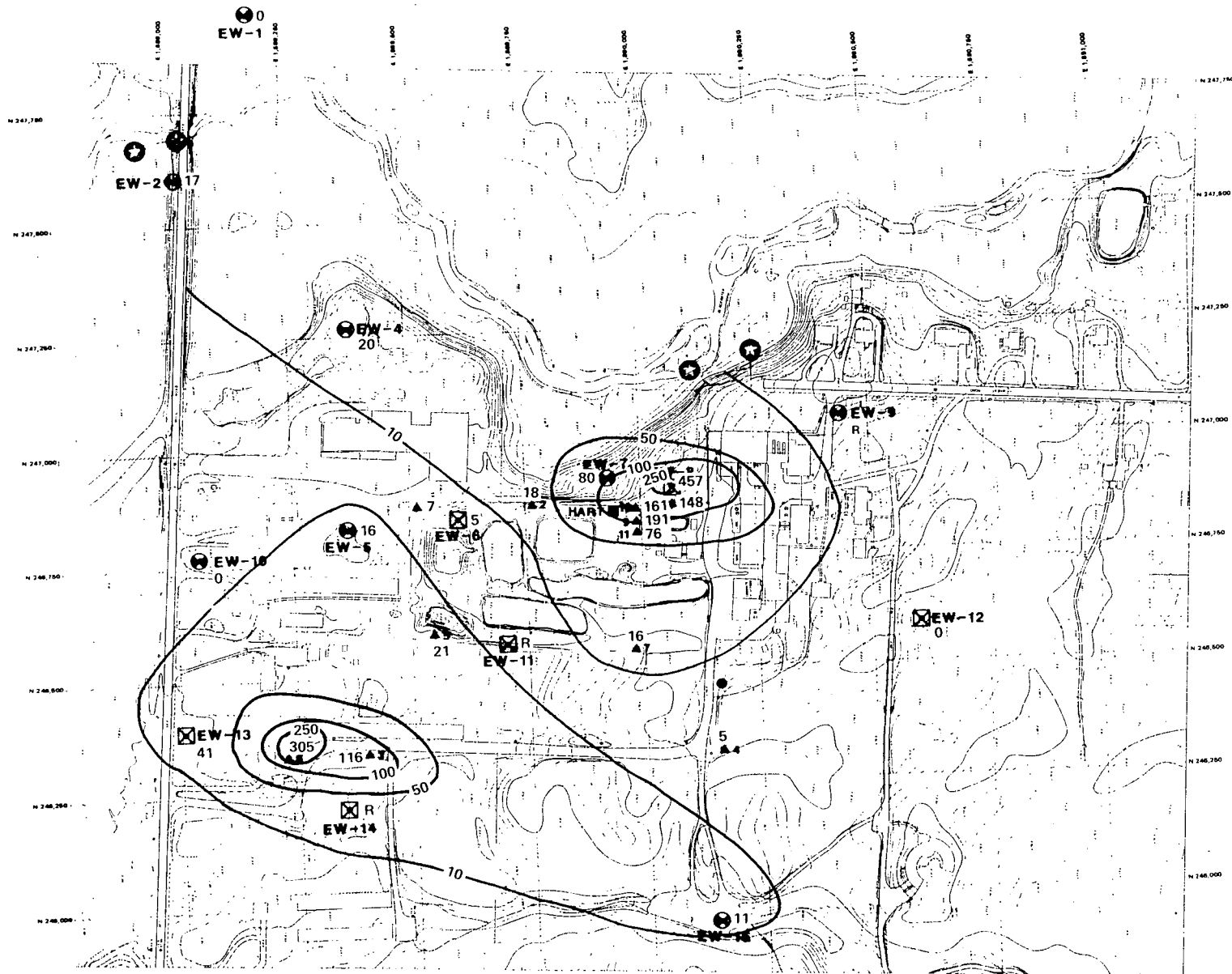
- GROUNDWATER [AS]: ppb
- U = UNDETECTED
 - [] = ESTIMATED VALUE
 - J = VALUE BETWEEN CRDL AND IDL
- ⊗ TRIPLE WELL CLUSTER (8)
 - ⊠ DOUBLE WELL CLUSTER (6)
 - ★ STREAM GAUGE STATIONS
 - ▲ EXISTING MONITORING WELLS (11)
 - PRODUCTION WELL (1)
 - HART (1)
 - LL LINED LAGOON
 - UU UNLINED LAGOON



TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

U.S. ENVIRONMENTAL PROTECTION AGENCY	VIN 001 1077
VINLAND CHEMICAL COMPANY SI	
FIGURE 4-9 AVERAGE ARSENIC CONCENTRAT DEEP WELLS	
EBASCO SERVICES INCORPOR	

VIN 001 1078



- GROUNDWATER (Cd):ppb
- TRIPLE WELL CLUSTER (8)
 - ⊠ DOUBLE WELL CLUSTER (6)
 - ★ STREAM GAUGE STATIONS
 - ▲ EXISTING MONITORING WELLS (11)
 - PRODUCTION WELL (1)
 - HART (1)

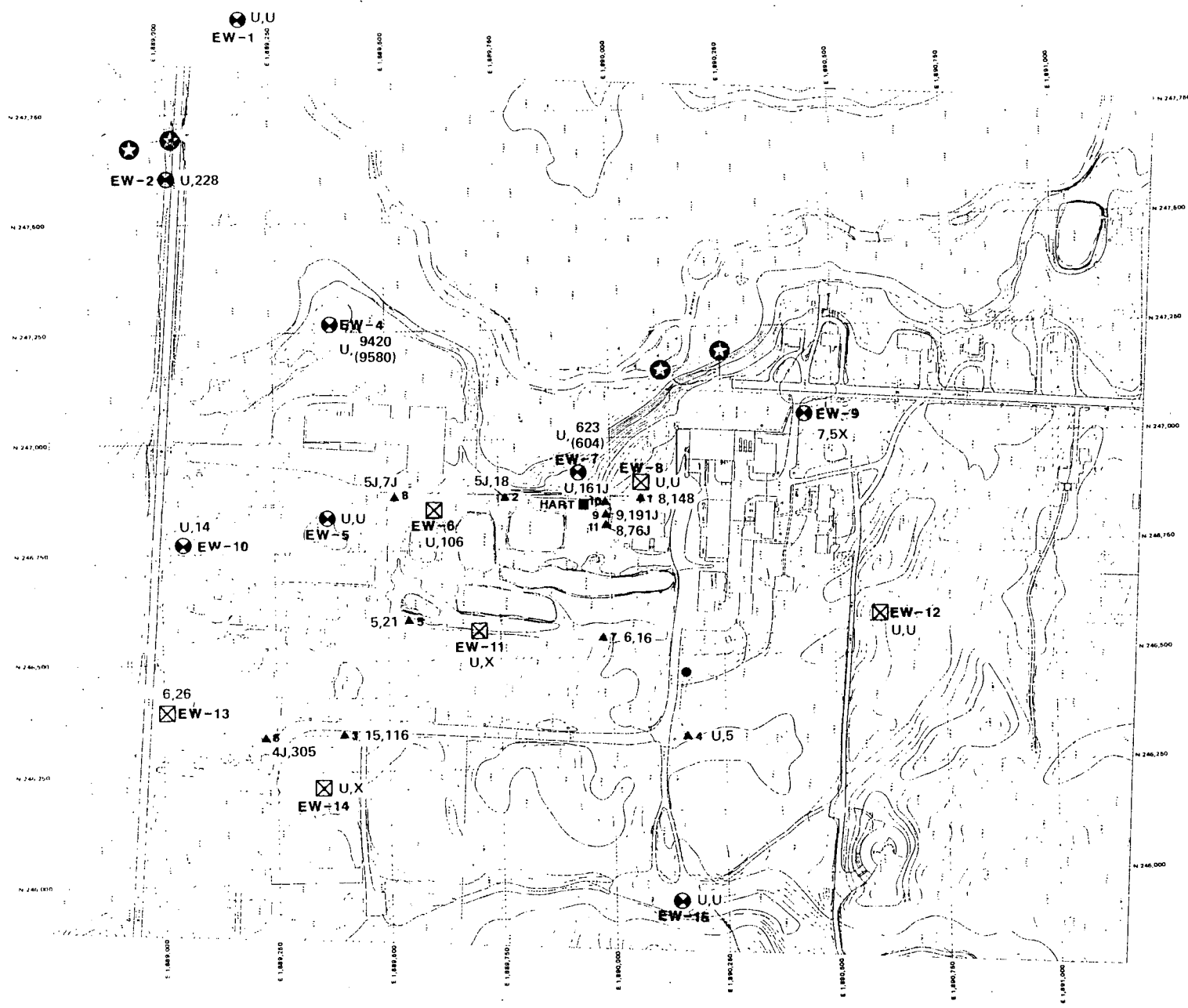
0 100 200 300
SCALE IN FEET

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

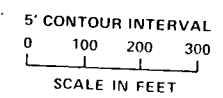
U.S. ENVIRONMENTAL PROTECTION AGENCY
VINELAND CHEMICAL COMPANY SITE
FIGURE 4-10
AVERAGE CADMIUM CONCENTRATION SHALLOW WELLS SEPT. 1987
EBASCO SERVICES INCORPORATE

VIN 001 1078

VIN 001 1079



- (GW1, GW2)
CADMIUM CONCENTRATION GROUNDWATER ($\mu\text{g/L}$)
DUPLICATE SAMPLES IN PARENTHESES
- ⊗ TRIPLE WELL CLUSTER (8)
 - ⊠ DOUBLE WELL CLUSTER (6)
 - ★ STREAM GAUGE STATIONS
 - ▲ EXISTING MONITORING WELLS (11)
 - PRODUCTION WELL (1)
 - HART (1)
 - LL LINED LAGOON
 - UL UNLINED LAGOON



TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY
ENGINEERS BY KUCERA INTERNATIONAL, JAN

U.S. ENVIRONMENTAL PROTECTION
AGENCY

VINELAND CHEMICAL COMPANY S

FIGURE 4-11

CADMIUM CONCENTRATION
IN GROUNDWATER, MEDIUM WELLS (

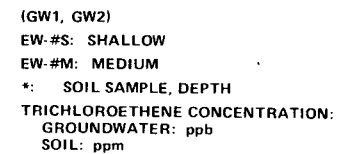
EBASCO SERVICES INCORPORATED







VIN 001 1079 OF 986

This is a topographic map of the Hart area, showing various points of interest, including EW-1 through EW-15, and a grid of coordinates. The map includes contour lines, roads, and buildings. The grid shows coordinates ranging from 1,885,000 to 1,891,000 Easting and 2,467,000 to 2,471,000 Northing. Key features include:

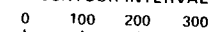
- EW-1**: Located at the top center, marked with a star and a circle.
- EW-2**: Located on the left side, marked with a star and a circle.
- EW-4**: Located in the upper left, marked with a star and a circle, with coordinates 5U,6.
- EW-5**: Located in the center-left, marked with a star and a circle, with coordinates *32 AT 45 FEET.
- EW-6**: Located in the center, marked with a star and a circle.
- EW-7**: Located in the center, marked with a star and a circle.
- EW-8**: Located in the center, marked with a star and a circle, with coordinates 5U,56.
- EW-9**: Located in the upper right, marked with a star and a circle.
- EW-10**: Located in the center-left, marked with a star and a circle.
- EW-11**: Located in the center, marked with a star and a circle.
- EW-12**: Located in the center-right, marked with a star and a circle.
- EW-13**: Located in the lower left, marked with a star and a circle, with coordinates 7,6.
- EW-14**: Located in the lower left, marked with a star and a circle, with coordinates 5U,190 and 42,260.
- EW-15**: Located in the lower right, marked with a star and a circle.

The map also shows a grid of coordinates ranging from 1,885,000 to 1,891,000 Easting and 2,467,000 to 2,471,000 Northing. Other features include a road labeled "HART", a building labeled "1,5U", and a point labeled "1600J".



-  **TRIPLE WELL CLUSTER (8)**
-  **DOUBLE WELL CLUSTER (6)**
-  **STREAM GAUGE STATIONS**
-  **EXISTING MONITORING WELLS (11)**
-  **PRODUCTION WELL (1)**
-  **HART (1)**

5' CONTOUR INTERVAL



SCALE IN FEET

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

U.S. ENVIRONMENTAL PROTECT
AGENCY

VINELAND CHEMICAL COMPANY

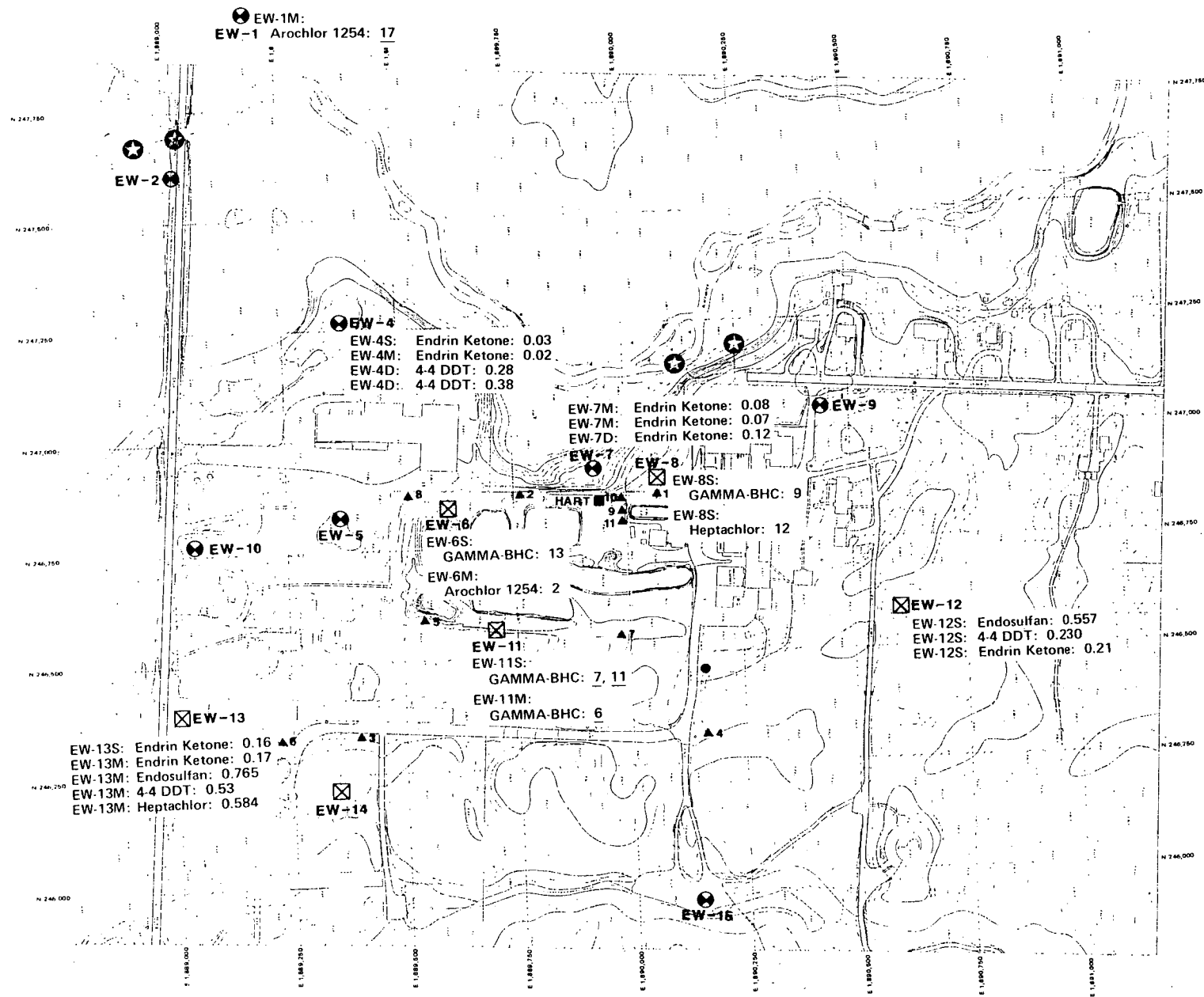
FIGURE 4-12

TRICHLOROETHENE CONTAMIN
IN GROUNDWATER AND SO

EBASCO SERVICES INCORPO.

VIN 001 1080

VIN 001 1081



TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

U.S. ENVIRONMENTAL PROTECT AGENCY	VIN 001 1081
VINELAND CHEMICAL COMPANY	
FIGURE 4-13 GROUNDWATER PESTICIDE/ PCB CONTAMINATION	
EBASCO SERVICES INCORPOR	

Figure 4-6 and Table 4-6 present various statistical analyses of the occurrence of arsenic, trichloroethene, lead and cadmium in the groundwater. Figure 4-6 shows that the majority of the hits for all of these contaminants occurred at the low end of the concentration ranges.

The concentrations of arsenic and cadmium in many of the groundwater samples were higher during the second round of sampling than the first. The reason for this is unknown. It is possible that this resulted from there being very little rainfall between the two sampling events in July and September, 1987 (see Figures 3-24 through 3-27).

Prior to obtaining groundwater samples, the monitoring wells were purged. The pH, temperature, and specific conductance of the groundwater was measured after purging each well volume, and at the end of purging. The final volume values for these parameters are presented in Table 4-6a.

The pH for the wells ranged between 4.5 and 8.4. The specific conductance was generally very low, often less than 100 umhos/cm. Well EW-4M had the highest specific conductance, approximately 2200 umhos/cm. This well also displayed the highest arsenic concentration. The generally low specific conductance values were supported by the high ground resistivity data seen in the geophysical investigation. These values indicate that the groundwater contains few dissolved salts.

The New Jersey Water Resources Data Report for the 1986 water year includes water quality data for three wells in Cumberland County. The specific conductance varied between 38 and 135 umhos/cm and the concentration of most dissolved constituents was low. The data from the site wells are consistent with this, except where arsenic contamination increases the dissolved solids concentration in the groundwater.

4.5 BUILDING #9 INVESTIGATION

Five soil borings were conducted inside Building #9, SB-25 through SB-29. Crystalline arsenic wastes were reportedly observed on top of the soils below the floor of this building in the past. This is one of the production buildings for the plant. The locations of the borings are shown in Figure 4-14.

Samples were taken every two feet to the top of the water table, approximately eight to ten feet below the base of the floor. Samples were analyzed for total arsenic. In addition, soil samples were analyzed for HSL organics and inorganics, and for EP toxicity metals. The analytical results are presented in Appendix A and are shown in Figure 4-14.

Unfortunately, many of the arsenic results were rejected in the data validation process. The results that are available suggest that arsenic concentrations are very high beneath the floor

VIN 001 1082

TABLE 4-6a

FINAL VOLUME
WATER QUALITY MEASUREMENTS
GROUNDWATER SAMPLING AT THE VINELAND CHEMICAL COMPANY

WELL	WELL VOLUME	GW-1: 7/21/87 - 7/30/87			GW-2: 9/15/87 - 9/30/87		
		pH (SU)	SP Cond. (umhos per cm)	TEMP. (°C)	pH (SU)	SP Cond. (umhos per cm)	TEMP. (°C)
EW-1S	Final Volume	4.5	70	16.5	5.9	49	15.0
EW-1M	Final Volume	5.8	200	14.5	5.9	80	19.0
EW-1D	Final Volume	5.6	130	17.0	5.9	80	16.0
EW-2S	Final Volume	6.4	50	18.5	5.7	115	19.0
EW-2M	Final Volume	7.1	160	16.5	6.4	170	15.0
EW-2D	Final Volume	6.5	50	17.0	5.5	46	14.0
EW-4S	Final Volume	4.9	170	19.0	4.9	60	19.0
EW-4M	Final Volume	7.0	2200	18.0	6.8	2100	16.5
EW-4D	Final Volume	5.4	125	17.0	5.5	45	15.5
EW-5S	Final Volume	5.5	0	22.0	6.4	170	19.0
EW-5M	Final Volume	5.5	30	21.0	5.6	330	17.0
EW-5D	Final Volume	6.0	50	16.0	6.0	80	16.0
EW-6S	Final Volume	5.2	100	16.5	5.8	115	17.0
EW-6M	Final Volume	6.6	340	16.0	7.0	540	15.0
EW-7S	Final Volume	6.3	245	15.0	5.9	140	16.0
EW-7M	Final Volume	6.6	235	16.0	6.1	290	15.5
EW-7D	Final Volume	7.9	130	16.5	5.4	110	15.5
EW-8S	Final Volume	6.3	205	16.5	6.3	260	17.0
EW-8M	Final Volume	5.6	50	16.0	5.1	12	15.0
EW-9S	Final Volume	5.5	10	17.5	4.9	15	16.0
EW-9M	Final Volume	6.0	18	17.0	6.2	150	14.0

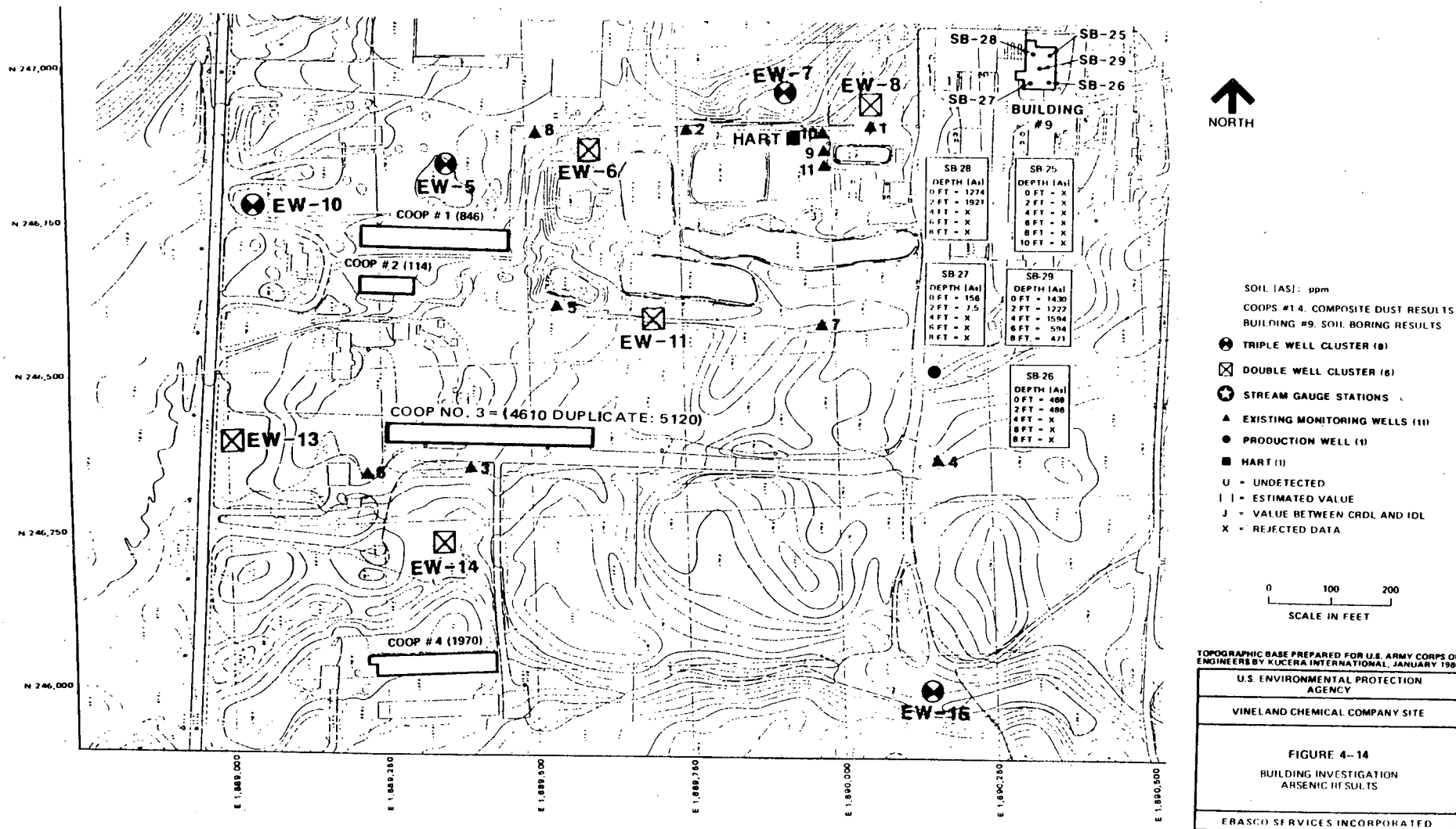
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TABLE 4-6a (Cont'd)

FINAL VOLUME
WATER QUALITY MEASUREMENTS
GROUNDWATER SAMPLING AT THE VINELAND CHEMICAL COMPANY

WELL	WELL VOLUME	GW-1: 7/21/87 - 7/30/87			GW-2: 9/15/87 - 9/30/87		
		pH (su)	SP Cond. (umhos per cm)	TEMP. (°C)	pH (su)	SP Cond. (umhos per cm)	TEMP. (°C)
EW-9D	Final Volume	5.5	0	15.5	6.5	70	14.0
EW-10S	Final Volume	5.3	140	17.5	5.4	160	20.0
EW-10M	Final Volume	6.4	350	17.5	6.4	350	20.0
EW-10D	Final Volume	5.1	290	18.0	5.2	265	17.0
EW-11S	Final Volume	5.7	240	18.0	6.0	125	20.5
EW-11M	Final Volume	6.1	280	17.0	5.8	300	16.0
EW-12S	Final Volume	5.2	50	14.5	4.7	50	15.5
EW-12M	Final Volume	5.9	60	15.0	5.2	75	13.5
EW-13S	Final Volume	6.0	185	17.0	4.9	130	17.0
EW-13M	Final Volume	6.7	220	17.0	6.1	210	15.5
EW-14S	Final Volume	5.5	10	20.5	5.8	120	18.0
EW-14M	Final Volume	5.5	3	16.0	5.9	50	14.0
EW-15S	Final Volume	6.0	75	17.0	5.4	85	18.5
EW-15M	Final Volume	7.0	100	15.0	8.0	120	13.5
EW-15D	Final Volume	8.4	105	15.0	7.1	110	13.5
MW-1	Final Volume	7.0	140	16.5	6.6	185	17.5
MW-2	Final Volume	7.4	110	18.5	6.7	170	21.5
MW-3	Final Volume	6.0	70	16.5	5.6	140	17.0
MW-4	Final Volume	5.5	150	14.0	4.9	20	15.0
MW-5	Final Volume	6.3	110	16.5	6.7	180	15.5
MW-6	Final Volume	5.5	110	16.0	5.8	190	16.0
MW-7	Final Volume	6.7	125	18.5	6.6	150	20.0
MW-8	Final Volume	6.0	130	17.5	5.6	190	18.0
MW-9	Final Volume	6.5	130	18.0	6.5	190	18.5
		5.7	90	20.5	6.0	140	20.5

4-32



this building. The detected concentrations range from approximately 8 to 1,921 mg/kg. Concentrations in SB-29 are higher at the top of the soil column than closer to the water table.

This building is actively used in the manufacturing process. The floor of the building is composed of one layer of brick over approximately one foot of concrete, as mentioned in Section 2. The layer of brick is in good shape, with no obvious cracks or deterioration. Therefore the significance of arsenic contamination in the soils below the floor relates to the possible leaching of arsenic from the soils as the water table rises and falls. Percolation of rainfall should not pose a problem since the floor essentially provides a cap to prevent infiltration. As shown in the results of SB-29, significant arsenic contamination does exist at the top of the water table, which is the most likely place to be contacted by a fluctuating water table.

4.6 CHICKEN COOPS

One composite dust sample was taken from each of the four chicken coops located at or near the ViChem plant site. These samples were analyzed for HSL inorganics. Table 4-7 presents a summary of the compounds detected, with the complete analytical results for each sample provided in Section VI of Appendix A. Figure 4-14 presented the arsenic concentrations found in the dust samples.

The principal inorganics found in the dust samples were arsenic, cadmium, lead, mercury and zinc. The first four of these are known to have been used at the plant and were found in the soils or the groundwater. Coop #3, adjacent to the former outdoor storage area in the southwest corner of the property, exhibited the highest concentrations of inorganics. This is the only coop presently used to store chemicals, as outlined in Section 2.

4.7 LAGOONS

Water samples were taken from all of the lagoons presently used in the water treatment system. This includes the two lined lagoons, LL-1 and LL-2, and the unlined lagoon UL-A. Sediment samples were also taken from UL-A. Recall that the lined lagoons store water to be treated, while the treated water from the treatment plant and non-contact cooling water are discharged into UL-A. None of the other lagoons on site are presently in use, however all of the lagoons were previously used to hold the formerly untreated process water.

The water samples were analyzed for HSL organics and inorganics and for dissolved arsenic. The sediment samples were analyzed for arsenic, iron, TOC, and grain size. One sediment sample was also analyzed for EP Toxicity metals. All of the analytical results are presented in Section VII of Appendix A. The

TABLE 4-7

SUMMARY OF CHEMICALS DETECTED IN
CHICKEN COOP DUST SAMPLES

mg/kg

<u>COMPOUND</u>	<u>NO. OF OCCUR.</u>	<u>NO. OF ANALYSES</u>	<u>MINIMUM DETECTED CONCEN- TRATION</u>	<u>MAXIMUM DETECTED CONCEN- TRATION</u>	<u>NO. OF ESTIM. VALUES</u>	<u>NO. OF REJECTED VALUES</u>
**Class: INORGANICS						
Aluminum	5	5	1680	3570	0	0
Antimony	5	5	4.3	55	1	0
Arsenic	5	5	114	5120	0	0
Barium	5	5	22	277	0	0
Beryllium	2	5	1.1	1.1	0	0
Cadmium	5	5	1.2	125	0	0
Calcium	5	5	17700	585000	0	0
Chromium	5	5	4.6	83	0	0
Cobalt	4	5	2.3	13	2	0
Copper	5	5	18	285	0	0
Iron	5	5	6240	118000	0	0
Lead	5	5	23	289	0	0
Magnesium	5	5	1480	3090	0	0
Manganese	5	5	138	567	0	0
Mercury	5	5	0.73	12.2	0	0
Nickel	4	5	20	108	0	0
Potassium	5	5	1900	4590	0	0
Selenium	4	5	0.16	0.7	4	0
Silver	2	5	4.3	4.7	0	0
Sodium	5	5	822	8980	2	0
Thallium	3	5	0.11	0.3	3	0
Vanadium	5	5	4.1	46	3	0
Zinc	5	5	370	1100	0	0

compounds detected in the water samples are summarized in Table 4-8. Figure 4-15 shows the arsenic concentrations in the lagoon sediment and water samples.

Arsenic was rejected in the unfiltered analyses from the three samples in the unlined lagoon, and was detected at very low concentrations (4 ug/l) in the filtered analyses. Arsenic was detected at 11 ug/l (unfiltered) and 8 ug/l (filtered) in the second round of analysis from the unlined lagoon. Arsenic was detected at concentrations up to approximately 3,500 ug/l in the water samples from the lined lagoons.

Other inorganics were present in the lagoon water at concentrations not considered unusually high. The only organic found was BEHP, a common contaminant.

Some arsenic was found in the sediment samples from the unlined lagoon. Arsenic was detected up to 185 mg/kg. The highest concentration of arsenic in one of the cores was seen at a depth of one to two feet below the sediment/water interface. Iron concentrations varied with the arsenic concentrations, being higher where the arsenic concentrations were higher. TOC concentrations ranged from 840 to 97,700 mg/kg. The grain size results showed that most of the sediment samples were composed of sand with very little fine material.

The results from the lagoon samples show some contamination, but not the levels seen in some of the groundwater samples. Recall, however, that in the past ViChem discharged untreated process water into the lagoons and allowed it to percolate into the groundwater, and stored waste salts on site and allowed them to dissolve and percolate into the groundwater. The effects of these previous releases are apparently still being seen in the groundwater beneath the site.

Field water quality tests were performed on the water samples from the lagoons. These results are shown in Table 4-9. The pH's are low, approximately 5 S.U. The specific conductance results are also low as was observed in the groundwater.

4.8 SURFACE WATER AND SEDIMENT

Surface water and sediment samples were taken from the Blackwater Branch and the Maurice River to as far as 38.5 river miles downstream of the site as part of the overall ViChem site RI. The results of this sampling will be the focus of the River Areas and the Union Lake RI reports. The results of the sampling from the stations closest to the ViChem plant site are presented here to add completeness to the environmental fate and transport of arsenic off of the plant site.

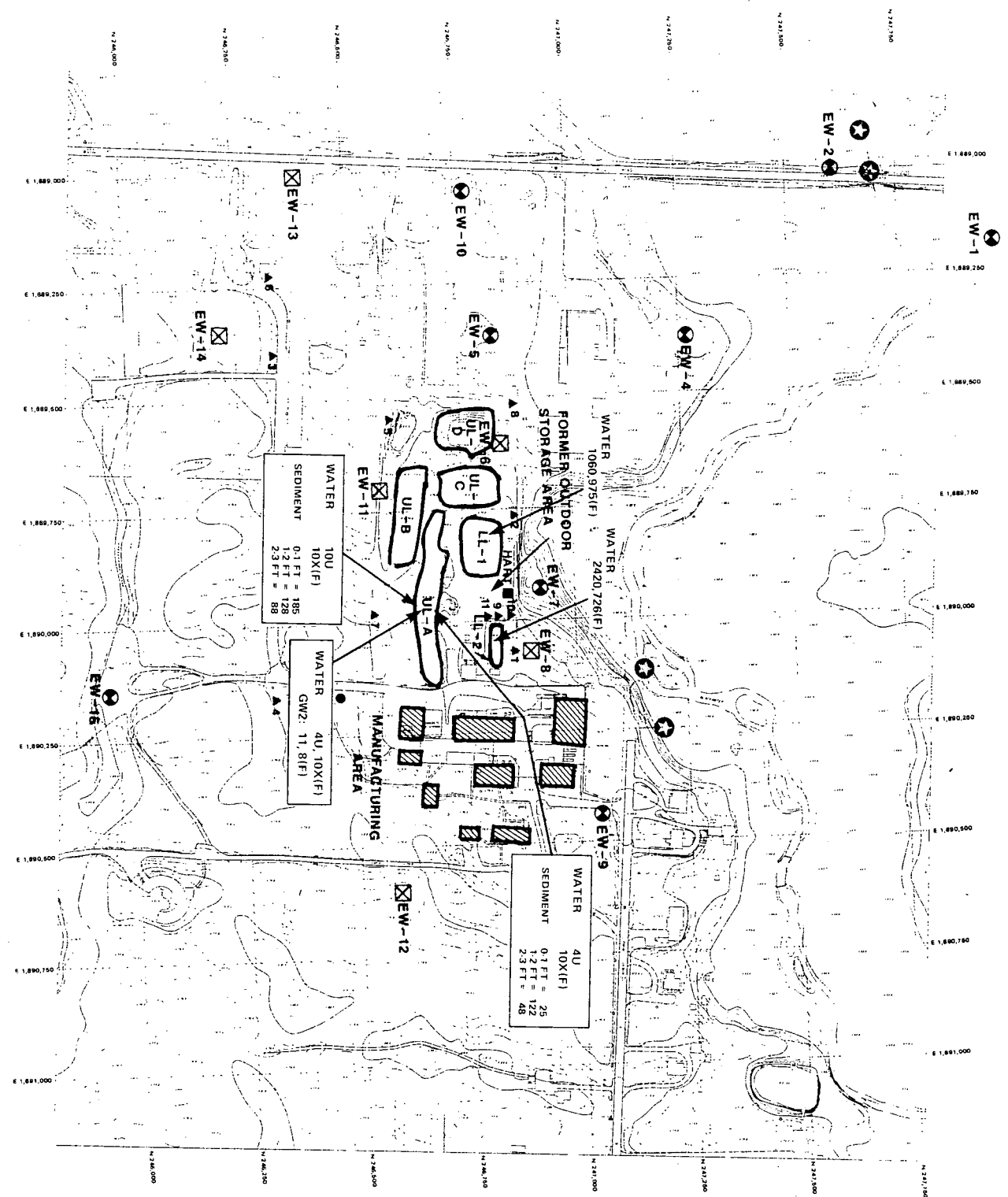
The surface water and sediment sampling locations are shown in Figure 4-16. Samples were taken from stations ER-4 and ER-3A in Phase I, and from ER-4, ER-3A, and ER-3 in Phase II. In phase I, sediment samples were analyzed for volatiles, HSL inorganics, and for arsenic, iron and TOC. Sediment samples were taken from

TABLE 4-8

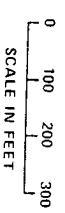
SUMMARY OF CHEMICALS DETECTED IN
LAGOON WATER SAMPLES

<u>COMPOUND</u>	<u>NO. OF OCCUR.</u>	<u>NO. OF ANALYSES</u>	<u>MINIMUM DETECTED CONCEN- TRATION</u>	<u>MAXIMUM DETECTED CONCEN- TRATION</u>	<u>NO. OF ESTIM. VALUES</u>	<u>NO. OF REJECTED VALUES</u>
** CLASS: BNA (ppb)						
BIS[2-ETHYLHEXYL]PHTHALATE	3	7	16	26	1	0
**CLASS: INORGANICS (ppm)						
ALUMINUM	4	7	279	4440	0	0
ANTIMONY	2	7	78	144	0	0
ARSENIC	4	7	11	3600	0	3
BARIUM	4	7	34	64	4	0
CALCIUM	4	7	450	6700	2	3
CHROMIUM	1	7	59	59	0	0
COBALT	1	7	20	20	1	0
COPPER	5	7	14	18	5	0
IRON	3	7	352	10100	0	4
MAGNESIUM	7	7	790	4580	7	0
MANGANESE	7	7	16	3750	0	0
MERCURY	4	7	0.2	1	0	0
NICKEL	1	7	121	121	0	4
POTASSIUM	5	7	360	5000	4	0
SODIUM	4	7	8230	20700	0	3
VANADIUM	2	7	11	11	2	0

VIN 001 1090



- GW2: SAMPLING EVENT #2
 SURFACE WATER (AS): ppb
 SEDIMENT (AS): ppm
 U = UNDETECTED
 X = REJECTED DATA
 F = FILTERED SAMPLE
- ⊗ TRIPLE WELL CLUSTER (8)
 - ⊠ DOUBLE WELL CLUSTER (6)
 - ⊕ STREAM GAUGE STATIONS
 - ▲ EXISTING MONITORING WELLS (11)
 - PRODUCTION WELL (1)
 - HART (1)
 - LL LINED LAGOON
 - UL UNLINED LAGOON



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VINLAND CHEMICAL COMPANY

FIGURE 4-15

LAGOON SAMPLING RE

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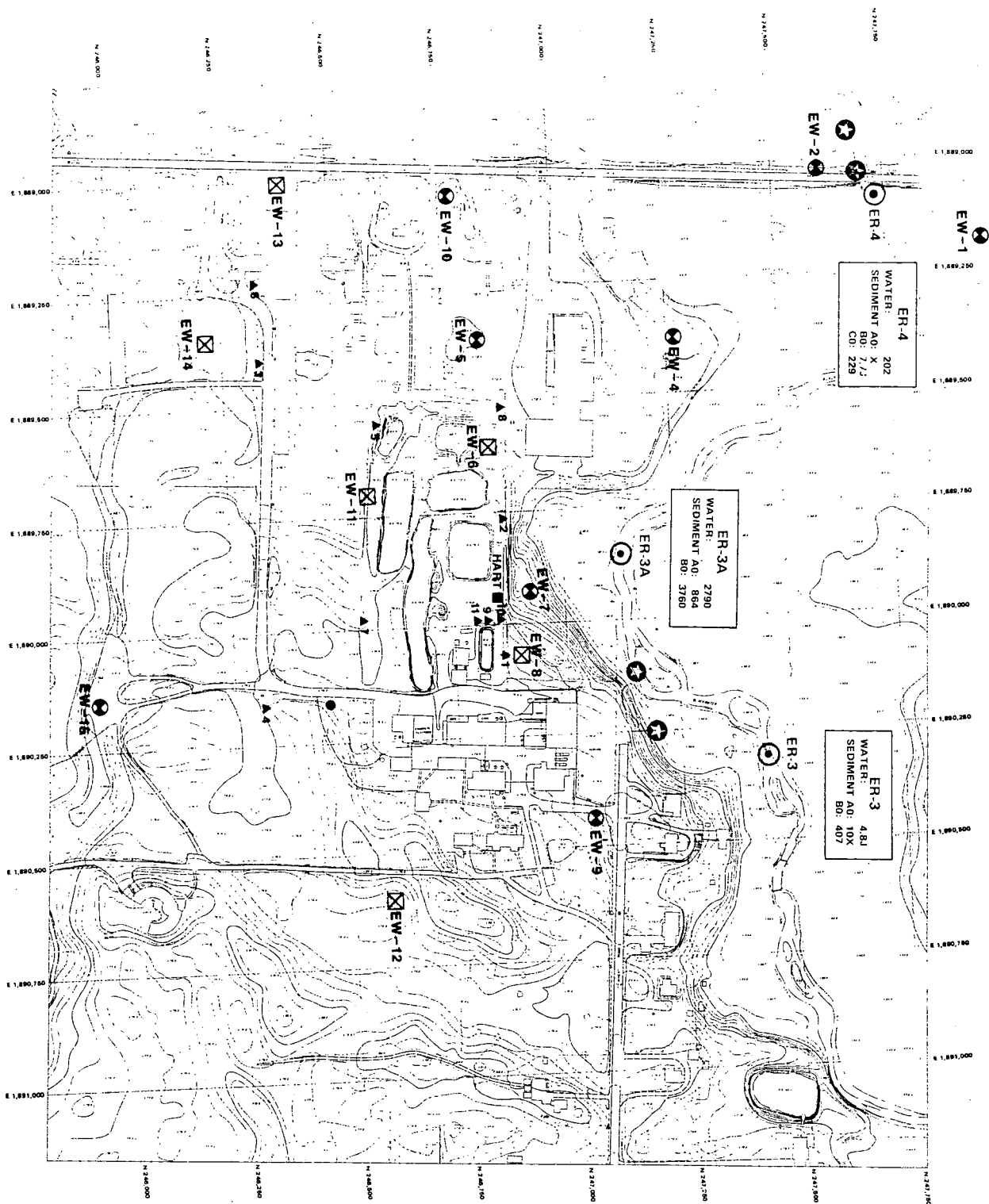
VIN 001 1090

TABLE 4-9

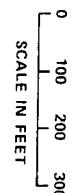
LAGOON WATER QUALITY
FIELD TESTS
PHASE II

SAMPLE NUMBER	DESCRIPTION	TEMPERATURE (°C)	pH (S.U.)	Eh (MU)	FIELD TESTS	
					SPECIFIC CONDUCTANCE (umhos/cm)	DISSOLVED OXYGEN (mg/l)
LAG-1	Unlined Lagoon Near Discharge	22	4.7	+230	125	6.4
LAG-2	Unlined Lagoon Near Middle	22.5	4.8	+230	50	5.2
LAG-3	Unlined Lagoon South End	22	5.3	+210	35	5.6

VIN 001 1092



- KEY:**
- SURFACE SAMPLING (AS) : ppm
 - SURFACE WATER (AS) : ppb
 - U = UNDETECTED
 - | | | ESTIMATED VALUE
 - J = VALUE BETWEEN CROD AND IDL
 - X = REJECTED DATA
 - SURFACE WATER AND SEDIMENT SAMPLING LOCATION
 - ⊗ TRIPLE WELL CLUSTER (8)
 - ⊠ DOUBLE WELL CLUSTER (6)
 - ⬆ STREAM GAUGE STATIONS
 - ▲ EXISTING MONITORING WELLS (11)
 - PRODUCTION WELL (1)
 - HART (1)



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U.S. ENVIRONMENTAL PROTECTION AGENCY

VINLAND CHEMICAL COMPANY SITE

FIGURE 4-16
SURFACE WATER AND SEDIMENT RESULTS

EBASCO SERVICES INCORPORAT

VIN 001 1092

the top one foot of the sediment column. In Phase II, sediment samples were analyzed for arsenic, iron, TOC and grain size. Sediment samples were taken from 0-1, 1-2, and 2-3 feet below the sediment/water interface. Phase I water samples were analyzed for volatiles and total and dissolved arsenic and iron. Phase II water samples were analyzed for dissolved arsenic and for HSL organics and inorganics. Table 4-10 presents statistical analyses of the Phase II surface water analyses. The results of all of the sampling are presented in Appendix A.

The sediment samples from the stations downstream from the site, ER-4 and ER-3A, display significant arsenic concentrations. The highest surface concentration was approximately 3,700 mg/kg at ER-3A. The arsenic concentration at depth was even higher, 6800 mg/kg, as shown in Appendix A. At the time the sediment samples were taken the beaver dam was still in place; therefore this sample was taken under approximately two feet of swampy water that used to occupy the Blackwater Branch flood plain.

Significant arsenic concentrations were also observed in the surface water. The highest concentration was again seen at ER-3A, approximately 3,000 ug/l. ER-4 also displayed elevated arsenic concentrations in the range of 200 ug/l. This is significantly above the Federal Primary Drinking Water Standard for arsenic, 50 ug/l.

These results will be discussed in detail in the River Areas RI report for the site. It is important to note here that arsenic contamination is observed in the surface water and the sediment of the Blackwater Branch downgradient of the site. The groundwater data presented previously showed a significant arsenic plume migrating off of the site towards the Blackwater Branch. As discussed previously, while the arsenic plume heads northwest of the plant toward well clusters EW-1 and EW-2, and while the surface water and sediments in the Blackwater Branch display significant arsenic contamination, no arsenic contamination was observed in well cluster EW-1. This cluster is across the Blackwater Branch from the site. The available data show that arsenic contamination in the shallow groundwater apparently discharges into the Blackwater Branch and does not cross under the stream.

4.9 SUMMARY

The nature and extent of the contamination at the ViChem plant site can be summarized as follows:

- o Surface Soils - High arsenic concentrations were observed in the surface soils in the lagoon area, along the plant road, near the destroyed chicken coops by cluster EW-14, and in the clearing by EW-15. All of these are areas of known or suspected past contamination. The soils on the plant periphery

TABLE 4-10

SUMMARY OF CHEMICALS DETECTED IN
SURFACE WATER SAMPLES

<u>COMPOUND</u>	<u>NO. OF OCCUR.</u>	<u>NO. OF ANALYSES</u>	<u>MINIMUM DETECTED CONCEN- TRATION (ppb)</u>	<u>MAXIMUM DETECTED CONCEN- TRATION (ppb)</u>	<u>NO. OF ESTIM. VALUES</u>	<u>NO. OF REJECTED VALUES</u>
**CLASS: VOLATILES						
METHYLENE CHLORIDE	1	3	4	4	1	1
**CLASS: BNA						
DI-n-BUTYLPHTHALATE	1	3	2	2	1	0
BIS(2-ETHYLHEXYL)PHTHALATE	1	3	0.6	0.6	1	0
**CLASS: INORGANICS						
ALUMINUM	2	3	332	506	0	0
ARSENIC	6	6	4.8	6200	1	0
BARIUM	3	3	66	111	3	0
CALCIUM	2	3	3600	5430	1	1
CHROMIUM	1	3	9.7	9.7	1	0
COPPER	3	3	15	27	2	0
IRON	1	3	124	124	0	2
LEAD	1	3	7.5	7.5	0	2
MAGNESIUM	3	3	1650	2480	3	0
MANGANESE	3	3	18.3	46	1	0
MERCURY	2	3	0.6	0.8	0	0
NICKEL	1	3	75	75	0	0
POTASSIUM	3	3	405	1430	3	0
SELENIUM	1	3	1.3	1.3	1	1
SODIUM	2	3	6500	6620	0	1
ZINC	1	3	65.1	65.1	1	2

generally displayed low or undetected arsenic concentrations. Soil contamination with arsenic is a fairly localized phenomenon.

- o Subsurface soils - The soil borings to the water table and the monitoring well soil samples to the water table showed elevated arsenic concentrations in the same locations where surface soil contamination was present. Again, the site periphery had low to undetected arsenic concentrations. The soils below the water table generally had low arsenic concentrations except near the banded zone. Only well cluster EW-7 showed elevated arsenic concentrations throughout the soil column to the banded zone. Very little arsenic contamination was observed below the banded zone.
- o Groundwater - The groundwater in the upper sand is contaminated with arsenic throughout the thickness of this unit. The arsenic plume follows groundwater flow to the north and northwest. The highest concentrations were observed at the base of the upper sand; however the plume is larger at the top of the upper sand. Very little arsenic contamination was observed in the groundwater below the banded zone. In addition to arsenic, there is cadmium and possibly TCE contamination in the upper sand.
- o Building #9 - The soils below the floor of building #9 are contaminated with substantial quantities of arsenic, even at depths where water table fluctuations could solubilize the arsenic. The floor of the building is covered and the area around the building is paved; therefore, there is little potential for rainfall percolation to solubilize the arsenic well above the water table.
- o Chicken Coops - The dust inside the chicken coops contains substantial quantities of arsenic, cadmium, lead, mercury and zinc. Only one of these coops is presently used to store process chemicals.
- o Lagoons - Water samples in the unlined lagoon showed very little arsenic, while samples in the lined lagoons showed arsenic up to 3,000 ug/l. Sediment samples from the unlined lagoon showed arsenic at approximately 120 mg/kg.
- o Surface Water and Sediment - Both the surface water and sediment downgradient of the site displayed elevated arsenic concentrations. The highest levels of contamination were observed in the former swamp caused by the beaver dam.

The data suggest that arsenic contamination in the upper sand is migrating off-site to the north and northwest and entering the Blackwater Branch. Both soil and groundwater sampled at well clusters EW-1 showed no detectable arsenic. This well cluster is across the Blackwater Branch from the site. The available data suggest that the arsenic contamination is entering the Branch, not flowing below it to the other side. This is supported by the physical hydrogeologic data presented in Section 3, which showed an upward hydraulic gradient on both sides of this stream.

While the data for this RI provided a significant body of information to define the arsenic contamination around the plant site, some additional data may be necessary to aid in designing a remedial action. Recommendations are provided below:

- o Groundwater - Additional monitoring wells should be installed to the west and south to fully define the extent of the arsenic plume in the upper sand aquifer.
- o Soils - Additional soil samples should be obtained if remedial action for soils contamination is performed. The samples will be necessary to definitively outline areas requiring remediation.
- o Buildings - Additional soil borings may be necessary to fully define the extent of arsenic contamination in the soils below the manufacturing area and buildings. The samples taken from underneath the floor of building #9 showed very high arsenic concentrations, and it is not known whether this will be seen in other areas as well. The need for additional soil borings will depend to a degree on the future plans for the site. Presently, the manufacturing area is paved, effectively capping the soils. This minimizes the potential for human contact, and minimizes rainfall percolation, which could solubilize any arsenic present. If the paving is not maintained permanently in the future and if arsenic contamination is widespread in these soils, then this could be a potential source of long-term contamination.



SECTION 5.0

VIN 001 1097

5.0 CONTAMINANT FATE AND TRANSPORT

5.1 ARSENIC

5.1.1 Geochemistry of Arsenic

Arsenic is ubiquitous in the earth's crust at low concentrations, generally below 5 mg/kg (USEPA, 1976). It occurs in four oxidation states: the -3 state, the metallic (0) state, and the +3 and +5 states. The metallic state can be found in certain types of mineral deposits while the +3 and +5 states are common in a variety of complex minerals and in dissolved salts in natural waters. The -3 state is present in gaseous AsH_3 (arsine). Arsenic occurs most frequently in nature in the pentavalent (+5) state as arsenate.

In soil, arsenic is present at concentrations from 0.1 ppm to more than 1,000 ppm, depending on the soil's geological history (Ehrich, 1981). Analysis of 1,577 U.S. surface waters showed arsenic to be present in 87 samples with concentrations ranging from 5 to 336 ug/l with a mean level of 64 ug/l (Kopp, 1969). In addition, large amounts of arsenic have been introduced into the environment in various chemical forms. Inorganic arsenic compounds such as sodium arsenite, lead arsenate and calcium arsenate have been used in agriculture; arsenic pentoxide is used as both a herbicide and a pesticide. Organic arsenic compounds such as monomethyl arsenic acid ($\text{CH}_3\text{AsO}(\text{OH})_2$) and dimethylarsenic acid ($(\text{CH}_3)_2\text{AsOOH}$) (also known as cacodylic acid) and their salts have been widely used as herbicides and pesticides. Smelting operations and coal burning power plants have also been principal sources of arsenic emissions into the environment.

Arsenic is mobile in the environment. Both natural and manmade arsenic can be cycled within the air, water, and soil by mechanisms such as oxidation/reduction, adsorption/desorption, precipitation/dissolution, and biological methylation and demethylation.

Aqueous Speciation

Arsenic occurs in natural waters as arsenate (+5), arsenite (+3) and methylated species. Arsenic acid (H_3AsO_4) and arsenious acid (H_3AsO_3) are formed from arsenate and arsenite respectively. Arsenious acid is formed from the dissolution of arsenious trioxide in water, whereas arsenic acid is formed from the dissolution of arsenic pentoxide in water.

Under the pe (log standard oxidation-reduction potential) and pH conditions typical of natural surface waters, the arsenate species (H_2AsO_4^- and HAsO_4^{2-}) predominate. Under moderately reducing (lower pe) aquatic conditions, the arsenite species H_3AsO_3 and H_2AsO_3^- are likely to predominate.

Of the two inorganic forms of arsenic, As^{+5} is the more soluble (Handbook of Chemistry and Physics, 1978). In solution it forms an oxyacid, H_3AsO_4 , whose properties very closely resemble those of H_3PO_4 . Its solubility is 302 gm/100 cc water (Handbook of Chemistry and Physics, 1978) at 12.5°C as $\text{H}_3\text{AsO}_4:1/2\text{H}_2\text{O}$. Once in solution, however, As(V) forms insoluble salts with many cations (Arsenic, 1984). Table 5-1 lists the solubility products for a range of arsenates.

As^{+3} has a solubility of 0.103M (41.6 gm/l as As_2O_3). Its behavior in solution is similar to that of boric acid, B(OH)_3 (Arsenic, 1984).

Evidence suggests that the arsenite (+3) form of arsenic is four to ten times more mobile in soil (and probably sediment) pore waters than is the arsenate (+5) species (Deuel and Swoboda, 1972). This is due to the formation of arsenate (As^{+5}) salts on the surface of sediment and soil materials. In many systems, this results from the presence of iron and manganese hydroxides which readily absorb As^{+5} into their matrices. The larger As^{+3} ion is probably not as readily absorbed in these structures. This suggests that under reducing pore-water conditions, redox reactions may increase the aqueous phase total arsenic concentrations.

In addition to direct effects on the solubility of arsenic itself, reducing conditions may indirectly increase arsenic concentrations through the reduction of ferric (+3) to ferrous (+2) iron and the accompanying dissolution of arsenic bearing amorphous iron oxides. The importance of iron redox reactions to arsenic cycling (similar to that of phosphorus) has been postulated by a number of authors including Deuel and Swoboda (1972) and Ferguson and Gavis (1972).

Evidence indicates that aqueous speciation of arsenic can be controlled by biological methylation and demethylation. Biomethylation of arsenicals is generally thought to occur in the anaerobic environment of the sediment. McBride & Wolfe (1971) showed that an anaerobic bacterium, Methanobacterium strain M.O.H could methylate arsenic and produced dimethylarsine (DMA) from As(V) , As(III) , and monomethylarsenic acid (MMAA). In addition to arsenic species, the cell extracts or whole cells of Methanobacterium required adenosine triphosphate, hydrogen, and methyl donors with methylcobalamine ($\text{CH}_3\text{-B}_{12}$) (Ridley, W.P. et al., 1977). This biomethylation and reduction process is shown in Figure 5-1. Moreover, three species of fungi, Candida humicola, Gliocladium species and a Penicillium species, were found to form trimethylarsine from methylated arsenic substrate at neutral or acid pH. The Candida was able to methylate dimethylarsinic acid, monomethyl arsenic acid, arsenate, and arsonite (Cox and Alexander, 1973). The trimethyl arsine and dimethylarsine formed can be released into the air. Figure 5-2 shows the biological cycle for arsenic. In addition, Andreae (1979) proposed that biological demethylation is responsible for the regeneration of inorganic arsenic from methylated arsenicals.

TABLE 5-1

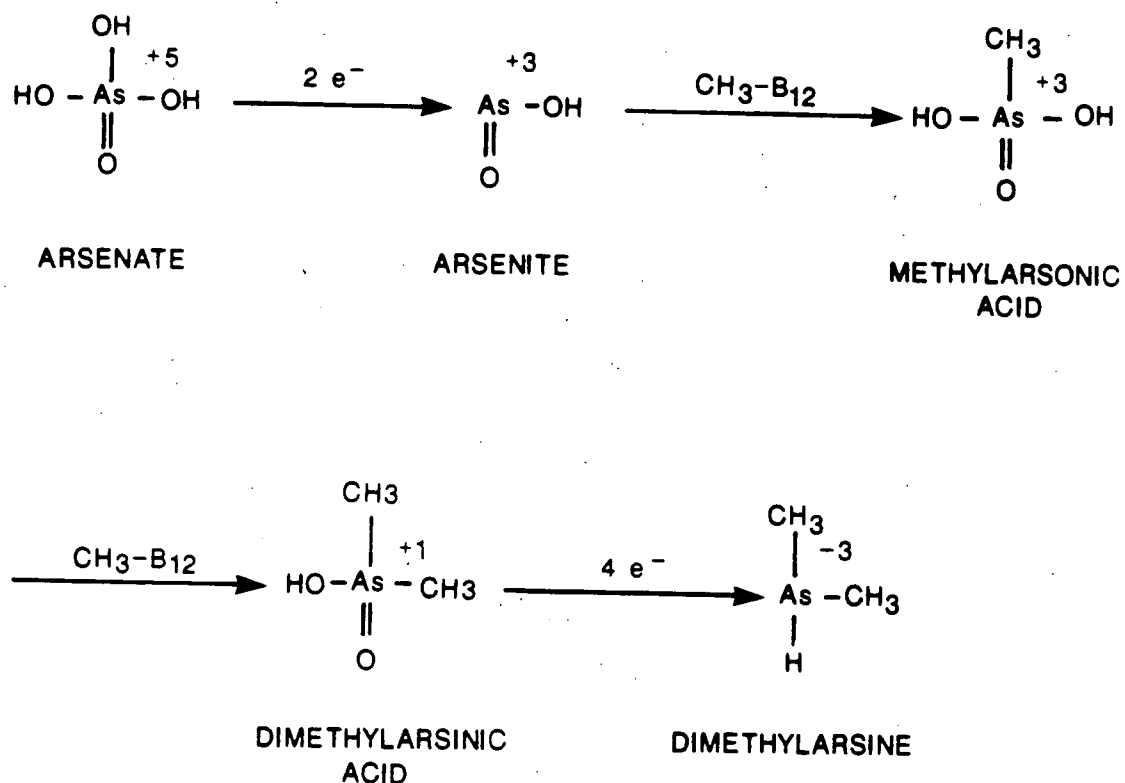
SOLUBILITY PRODUCTS FOR ARSENATES¹

Solids in Equilibrium	Solubility Product Log K _{sp}
AlAsO ₄	-15.8
Ba ₃ (AsO ₄) ₂	-50.11
Ca ₃ (AsO ₄) ₂	-18.16
Cd ₃ (AsO ₄) ₂	-32.6
Co ₃ (AsO ₄) ₂	-28.1
Cu ₃ (AsO ₄) ₂	-35.1
Cr AsO ₄	-20.1
Fe AsO ₄	-20.2
Mg ₃ (AsO ₄) ₂	-19.6
Ni ₃ (AsO ₄) ₂	-25.5
Pb(AsO ₄) ₂	-34.4
Sr ₃ (AsO ₄) ₂	-18.1
Zn(AsO ₄) ₂	-27.4
Mn ₃ (AsO ₄) ₂	-28.7

Where, for example $K_{sp_{FeAsO_4}} = [Fe^{+3}] [AsO_4^{-3}]$

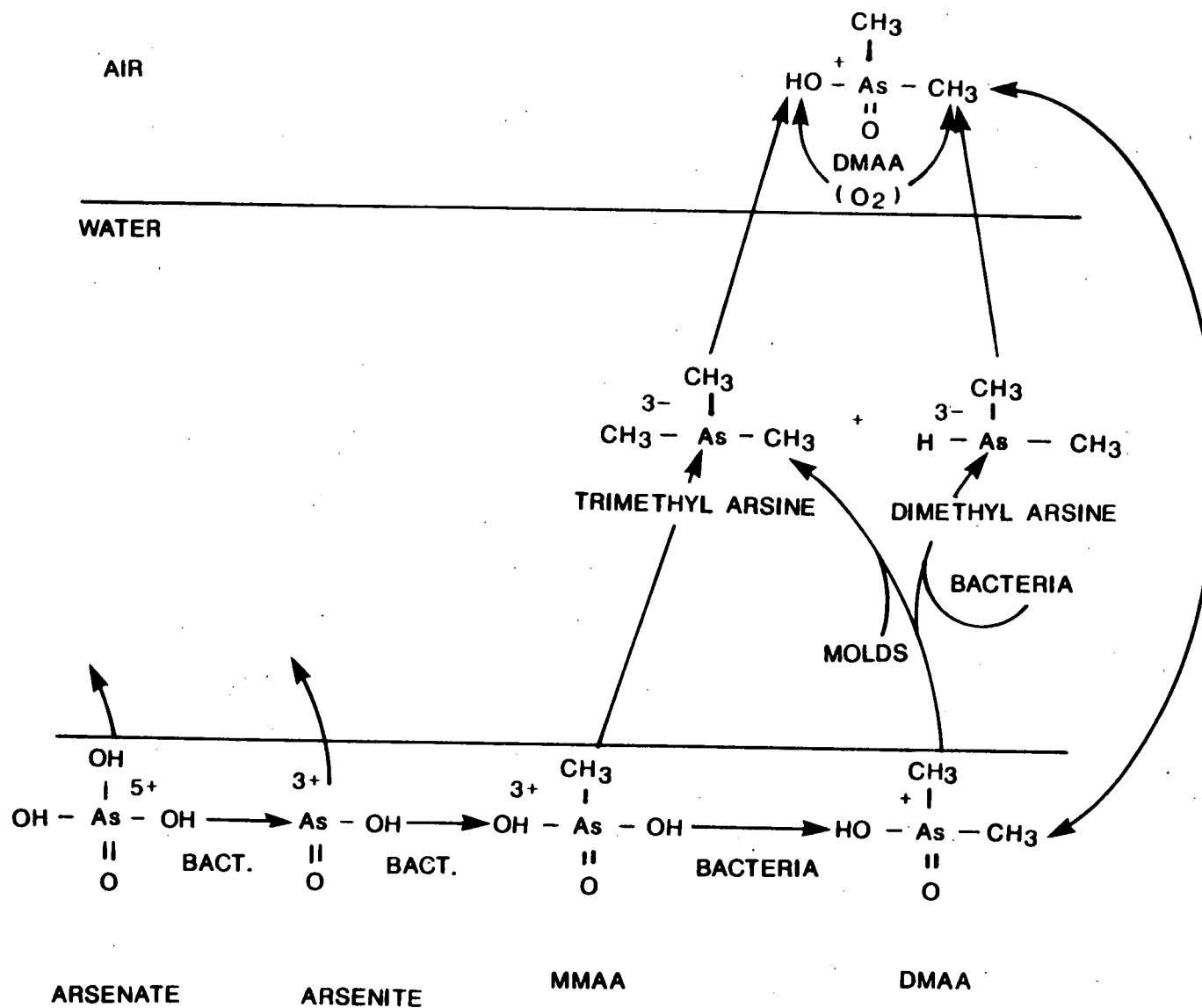
- ¹ From Frankenthal, R.P., 1963. Equilibrium constants. In: Handbook of Analytical Chemistry, 1st Edition (edited by Meites, L.) Pl-13 to 1-19, McGraw Hill, Toronto.

FIGURE 5-1
BACTERIAL REDUCTION OF ARSENATE



SOURCE: Mc BRIDE & WOLFE, 1971

FIGURE 5-2
THE BIOLOGICAL CYCLE FOR ARSENIC



Precipitation/Dissolution

Arsenic can form insoluble precipitates with calcium, sulfur, iron, aluminum and barium compounds in natural waters. These reactions have been proposed as controls on aqueous phase arsenic concentrations (Deuel and Swoboda, 1972). Arsenic sulfide (As_2S_3) is suggested as being of particular importance under reducing conditions. However, since the nucleation and growth rate of the arsenical precipitates are slow (Wagemann, 1978), soluble arsenic species are more likely to be adsorbed on the surface of inorganic and organic substrates.

Adsorption/Desorption

Arsenic occurs in soil/sediment predominantly in an insoluble/adsorbed form. Arsenic has been shown to be adsorbed by a variety of sediment solid phase components including hydrous iron, aluminum and calcium oxides, clays and soil organic matter. In most geologic environments, evidence suggests the importance of soil iron oxides in adsorbing negatively charged anions such as arsenate preferentially. Woolson *et al.* (1971) found that most of the arsenic residue from soil with a history of arsenic applications was found as Fe-As. Other forms, Al-As and Ca-As, may predominate if the amount of "reactive" Al or Ca is high, and reactive Fe is low. Arsenic adsorption appears to be better correlated to the clay content of the soil than to soil organic carbon content (Jacobs *et al.*, 1970 and Wauchope, 1975). The reason for this relationship is that the hydrous iron and aluminum oxide contents of soils usually vary directly with the clay content of the soil.

For certain organic arsenate compounds, however, soil organic content may be a significant factor in overall mobility (Clement and Faust, 1981). Hydrous oxides also appear to be more effective adsorbers of arsenic on a surface area basis than are layer silicate components of clays. The adsorption process appears to be dependent upon both system pH and reduction-oxidation (redox) conditions. Maximum adsorption of arsenic as arsenate (+5) occurs under acidic or neutral pH conditions, with decreasing adsorption with increasing pH over the pH 7-9 range. The maximum adsorption of arsenic as arsenite (+3) on hydrous oxides appears to occur in the pH 7-9 range. (Rai and Zachara, 1984). Also, Gupta & Chen (1978) showed that the rate of adsorption decreases with increasing salinity and pentavalent species have a greater adsorption affinity than do trivalent species. These data show that adsorption will be most important in aerobic, fresh water. As conditions become more reducing, alkaline, and/or saline, arsenic is less likely to be adsorbed and more likely to remain dissolved.

The relationships between the concentration of arsenic adsorbed or desorbed to solid phase soils or sediments and the aqueous phase arsenic concentration may be expressed in terms of a partition or distribution coefficient (K):

$$K = X/C \quad (1)$$

where:

- X = amount of arsenic adsorbed to the solid phase in mg/kg,
and
- C = aqueous arsenic concentration in mg/l.

Factors which have been demonstrated to influence the magnitude of K for a constituent such as arsenic include:

- o the experimental aqueous concentration range studied;
- o the form and valence of arsenic;
- o solution pH; and
- o solid/solution ratios.

Experimentally measured arsenic partition coefficients have been reported by a number of researchers for both sediments and soils of differing chemical composition.

Partition coefficient (K) values for arsenic adsorption (as arsenate) to three different U.S. soils have been estimated from the linear portions of Langmuir isotherms of data reported by Jacobs et al. (1970) and are found to be 8-28 l/kg. Estimated partition coefficients have been calculated from data reported for the adsorption of arsenic (as arsenate) to sediment (Wauchope and McDowell, 1984), and are estimated to be 19-102 l/kg.

Wauchope (1975) also observed that the partitioning of two organic arsenic herbicide compounds (methanearsonate - $H_2AsO_3CH_3$ and cacodylate - $HAsO_2(CH_3)_2$) was generally similar to that of the inorganic arsenic. For equivalent initial solution arsenic concentrations (2.5×10^{-3} M), maximum calculated K values (methanearsonate, K=75; cacodylate, K=46) are less than the maximum K values calculated for inorganic arsenate.

Available evidence indicates that the adsorption of arsenic to soils/sediment is not entirely reversible. Elkhatib et al. (1984) and Winka (1985) reported that isotherms of arsenite desorption from soils were strongly hysteretic. That is, for comparable experimental time frames, a fraction of previously adsorbed arsenic appeared to be irreversibly bound to the soil phase. In general, partition coefficients for desorption (K_d) were significantly greater than the analogous K values for adsorption. This suggests that the use of partition coefficients based on measured adsorption K values may not appropriately describe the current mobility of arsenic at sites of past contamination. Arsenic migration in most field systems is predominantly controlled by arsenic desorption from the solid phase. Therefore, it is the magnitude of K_d that is most appropriately applied to environmental fate studies.

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Available information indicates that K_d for soil desorption is:

- o Significantly greater than K for adsorption;
- o A function of soil chemical composition, including soil pH and iron oxide concentration; and
- o Strongly affected by the soil redox levels.

Partitioning to Sediments

The partitioning of arsenic between natural waters and sediments may be controlled by both precipitation and adsorption processes. At low aqueous phase arsenic concentrations, sediment-water partitioning may be predominantly controlled by adsorption/desorption processes rather than by direct precipitation (Clement and Faust, 1981).

In general, when runoff occurs, dissolved arsenic is accumulated in the sediment by three interrelated processes: sediment loading, solute adsorption onto the sediment, and "entrapment" in adsorbed solute as heavier sediment particles are left behind. The adsorption of arsenic to sediment is not an entirely reversible process, and the sediment usually acts as a sink for arsenic. Faust *et al.* (1983) have shown that the arsenic concentrations in sediment at the bottom of Union Lake were as much as three orders of magnitude higher than in the overlying waters.

Gas Transfer From Soils

A study by Woolson and Kearney, 1972 showed that significant amounts of cacodylic acid (dimethylarsenic acid) can be volatilized in the soil via biological activity. Any of the biological processes that produce dimethyl or trimethyl arsines provide a means for gas exchange flux from the soils. However, quantifying this flux is quite difficult since the reaction rates are not well known.

5.1.2 Arsenic at the ViChem Site

As discussed previously, arsenic solubility and adsorption are strongly dependent on the redox conditions in solution. Data collected at the site suggested that variations in these conditions may be responsible for controlling arsenic transport via site groundwater. Two terms can be used to describe the redox condition of a solution; pe and E_h .

pe is defined as follows:

$$pe = - \log (e)$$

where (e) is the activity of a hypothetical electron in solution. The p_e is the electron equivalent of pH for the hydrogen ion activity. The p_e is related to the readily measured redox potential E_h as follows:

$$p_e = \frac{F}{2.303 RT} E_h$$

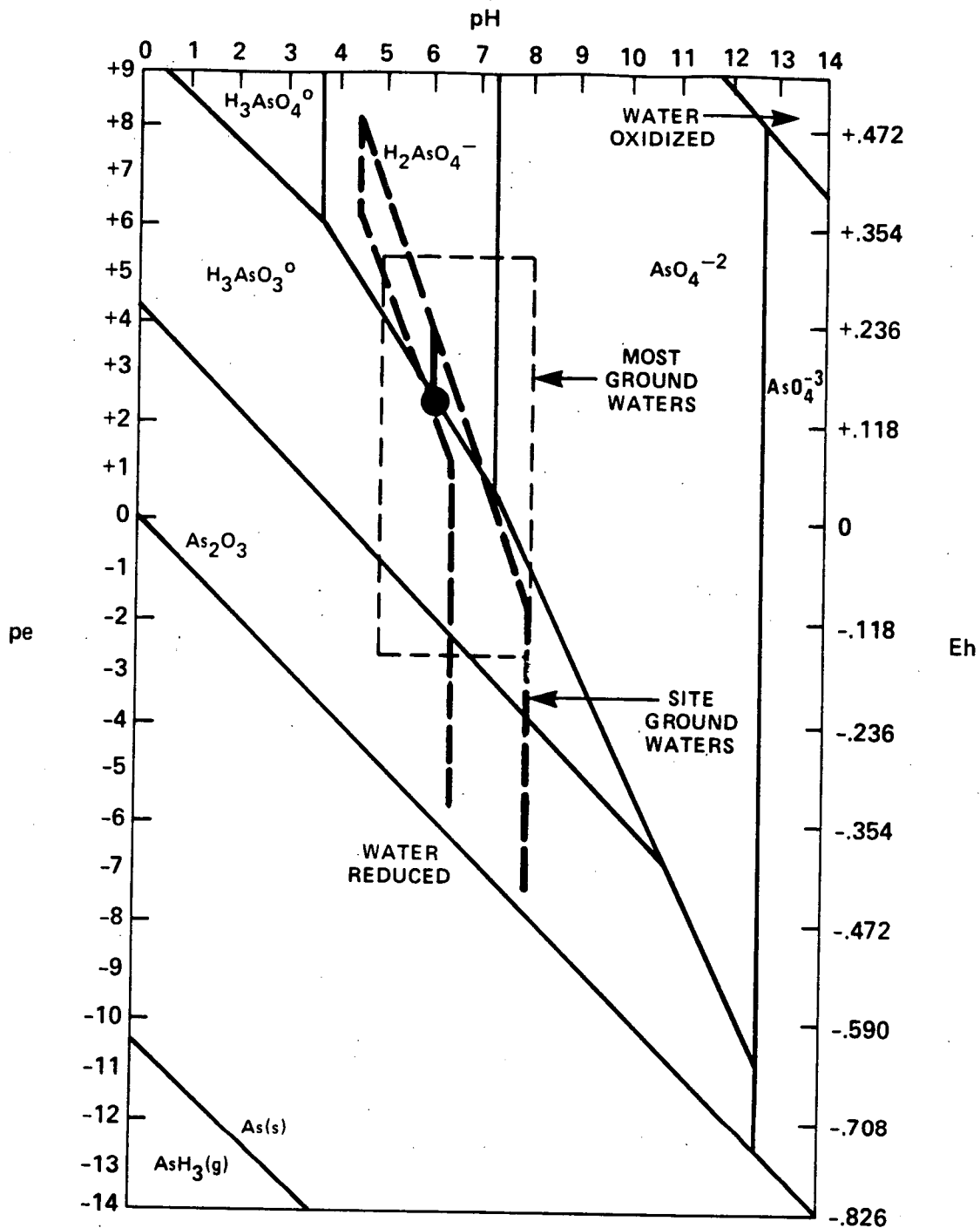
where: F = Faraday's constant (23.06 kcal/V-gm equivalent)
 R = the gas constant (1.987×10^{-3} kcal/mole $^{\circ}$ K)
 T = the absolute temperature ($^{\circ}$ K)
 E_h = the redox potential (V)

The oxidation-reduction stability diagram for arsenic compounds is shown in Figure 5-3. Superimposed on the theoretical plot are site-specific conditions for the ViChem site. The vertical line represents a median pH value of 5.9, for the groundwater under the site. Assuming little or no change in this pH value, the redox conditions of site groundwater would move up and down the vertical dotted line. The p_e values within the box in Figure 5-3 represent redox conditions that were determined by an analysis of the total iron of the well water samples collected on the site.

In order to estimate the redox conditions from the total iron analysis, two assumptions were necessary. First, since no data were available for dissolved iron, the total iron values are assumed to represent only dissolved iron. The close agreement between total and dissolved arsenic at the site wells, the very clean sand of the aquifer, and the fact that the groundwater samples were very clear support to this assumption. Second, the concentration of iron in the water is assumed to be thermodynamically stable, i.e., not influenced by organic species or biological activity. Based on these assumptions, it is then possible to determine a p_e from the pH and iron concentration found in the aquifer below the site using equilibria relationships given in Lindsay, 1979.

Using the median pH (5.9) and geometric mean iron concentration (5000 ppb or 89 μ mole/l) in shallow and medium depth groundwater, iron equilibria yield a p_e of 2.15 ($E_h = 0.127V$ at $25^{\circ}C$). The range of all measured pH (4.5 to 8) and iron concentrations (433 to 38,400 μ g/l or 77 to 690 μ mole/l) yield the p_e range of -8 to 8, shown in Figure 5-4. This yields the spectrum of possible site conditions shown in Figure 5-3. These p_e values correspond well with the conditions typical of most groundwaters. Figure 5-4 also shows an area where the measured iron levels are significantly above saturation, making accurate selection of p_e conditions above pH=7.5 difficult and suggesting that the assumption that total iron equals dissolved iron may not be valid everywhere in the aquifer. Lacking any other information though, this is the best estimation that can be made. Note that both Figures 5-3 and 5-4 show iron and arsenic conditions with no sulfur or chloride present. These conditions were chosen based on U.S.G.S. measurements at Norma,

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BASED ON CLEMENT & FAUST, 1973 AND
FERGUSON & GAVIS, 1972.

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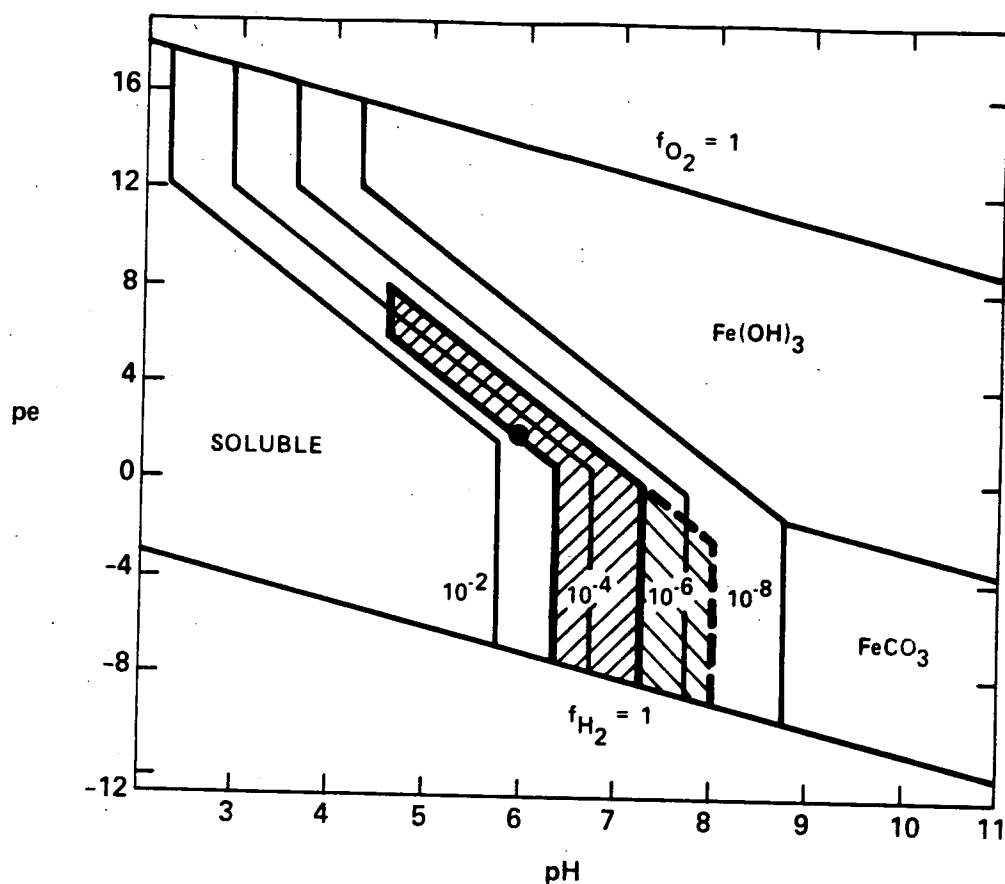
VINELAND CHEMICAL COMPANY SITE

FIGURE 5-3

pH-pe OXIDATION-REDUCTION STABILITY
DIAGRAM FOR ARSENIC COMPOUND

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VIN 001 - 1107



Contours of dissolved iron activity as a function of pe and pH. $P_{\text{CO}_2} = 10^{-2}$, no dissolved sulfur species present. $\text{Fe(OH)}_3_{\text{soil}}$ is the source of the dissolved iron.

● MEAN AQUIFER CONDITIONS

▨ RANGE OF PE CONDITIONS AS DEFINED BY SITE pH AND IRON CONCENTRATIONS.

▨ EXTRAPOLATED RANGE OF pe CONDITIONS BASED ON pH ALONE. IRON VALUES MEASURED IN SAMPLES FROM THIS pH RANGE ARE ABOVE SATURATION AND THEREFORE CANNOT BE USED ON THIS EQUILIBRIUM DIAGRAM. ONLY 3 OF THE 58 pH MEASUREMENTS FALL IN THIS AREA SO THAT THE AREA IS ESSENTIALLY UNIMPORTANT FOR MOST SITE CONDITIONS.

BASED ON DREVER, 1982 AND LINDSAY, 1980.

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FIGURE 5-4
pH-pe OXIDATION-REDUCTION
DIAGRAM FOR IRON SOLUBILITY
UNDER SITE CONDITIONS

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NJ on the Maurice River, which show sulfur and chloride levels to be less than 10^{-4} mole/l. The Maurice River study area includes the Blackwater Branch and the plant site in its drainage basin. This USGS station provides the most proximate water quality data available and is assumed to reflect the site groundwater conditions, at least for these two constituents.

Based on these arguments, the oxidation state of arsenic in the groundwater will vary between +5 as H_2AsO_4^- and +3 as H_3AsO_3^0 , assuming thermodynamic equilibrium. Based on the range of oxidation states, the K_d for arsenic should vary significantly as previously discussed in Subsection 5.1.1. This would help to explain the broad range of K_d seen in the site aquifer and discussed below.

The K_d s for arsenic for the wells in the upper sand are shown in Table 5-2. These values were calculated from the analyses of total arsenic in the soil sample at the screen setting and the total arsenic in the groundwater as follows:

$$K_d = \frac{\text{total Arsenic in soil in mg/kg}}{\text{total Arsenic in groundwater in mg/l}}$$

No apparent trend is readily visible separating the shallow and medium wells in the upper sand. However, when dissolved arsenic levels are detected near background levels, the corresponding K_d is always very high (see Figure 5-5a). This is probably the result of arsenic bound within the soil material, not interacting with the groundwater, thus yielding these very high values.

When K_d is plotted against total iron in the groundwater, it is readily apparent that no high values of K_d occur above iron levels of 8 mg/kg (see Figure 5-5b). This would support the relationship between iron concentrations, arsenic oxidation states and the K_d previously discussed.

The range of K_d for the contaminated mid-depth wells is 0.2 to 54 l/kg with a geometric mean value of 6.6 l/kg. The range of K_d for the contaminated surface wells is <1.5 to 270 with a geometric mean of 9.8 l/kg. These mean values agree well with the mean K_d of 5 l/kg for a mixture of As (III) and As (V) in sandy soils measured by Baes and Sharp, 1983. Thus, the limiting factor for dissolved arsenic concentration in the groundwater is the variation of K_d within the aquifer, not the arsenic solubility.

Considering the above, the average K_d for arsenic in the soils at the ViChem site was estimated to range from 6 to 10. Practically speaking, the concentration of arsenic in the soils is expected to be 6 to 10 times as great as the concentration of arsenic in waters in equilibrium with the soils, when the soil concentration is expressed as mg/kg and the water concentration is expressed as mg/l.

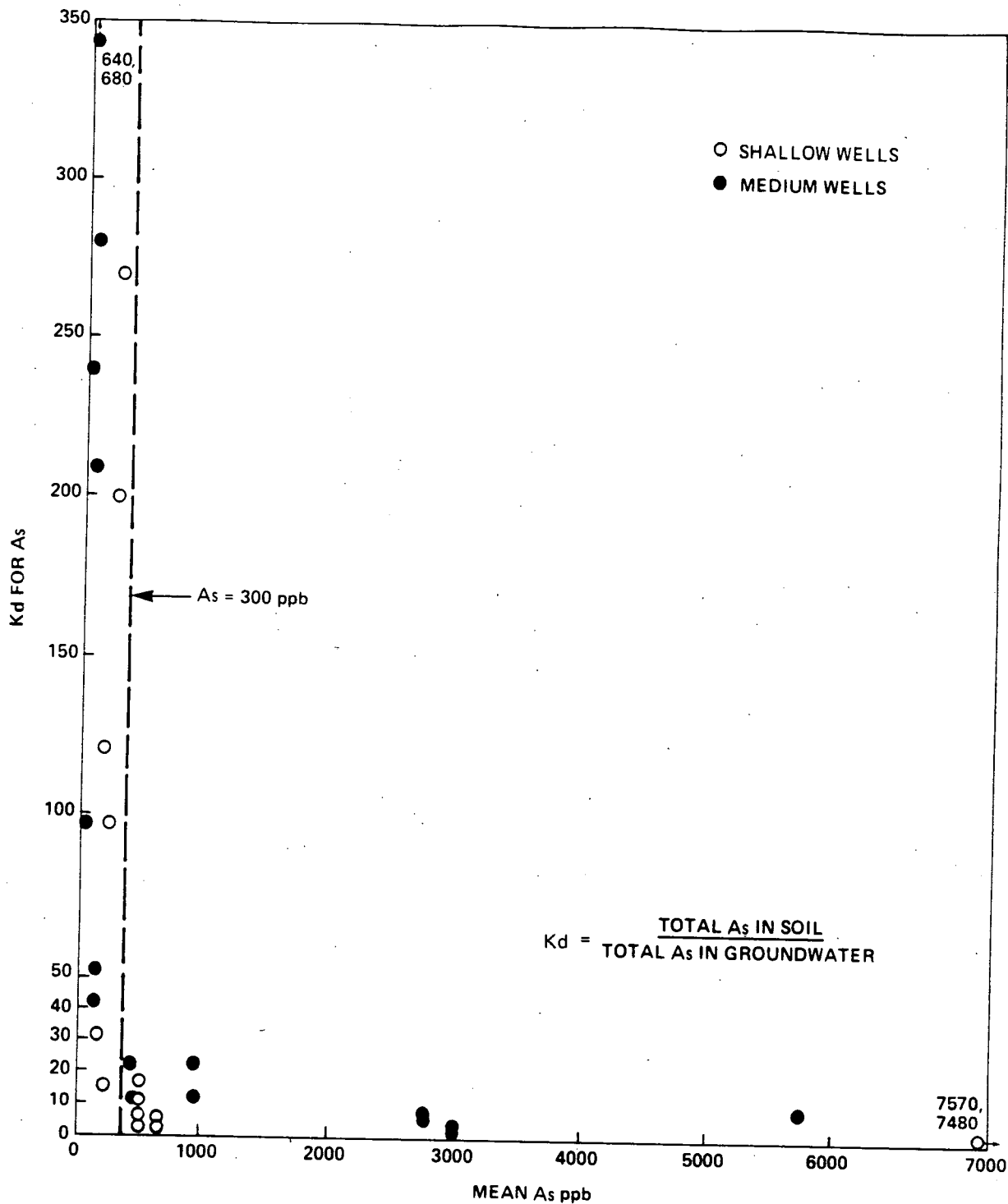
TABLE 5-2

SUMMARY OF DISTRIBUTION COEFFICIENTS FOR As AT
THE VINELAND CHEMICAL COMPANY SITE

Well	Depth ft.	Kd**		Groundwater Total Fe	Groundwater Diss. As
		GW-1	GW-2	Mean	Mean
MEDIUM WELLS				(ug/l)	(ug/l)
EW-2M	30	10.	10.	11100	5760
EW-4M	37	0.2	0.2	11300	310,000
EW-5M	43	620	240	4230	22
EW-6M	60	2.4	3.0	36700	2940
EW-7M	55	6.0	6.0	17,600	14,700
EW-8M	70	54	42	734	120
EW-10M	33	22	12	4700	427
EW-11M	60	9.0	8.0	24100	2790
EW-13M	50	13	23	3620	937
EW-14M	60	280	210	6630	15
EW-15M	62	98	680	550	18*
SHALLOW WELLS					
EW-4S	8	2.4	1.6	534	641
EW-5S	8	17	12	14,000	507
EW-6S	13	120	31	4475	164
EW-7S	5	0.55	0.60	1660	7480
EW-8S	13	3.0	2.0	11200	7570
EW-13S	17	5.0	3.0	3,200	771
EW-14S	12	99	15	486	225
EW-15S	13	200	270	--	260

* Total As in groundwater

** Calculated with Total As in soil and Total As in groundwater



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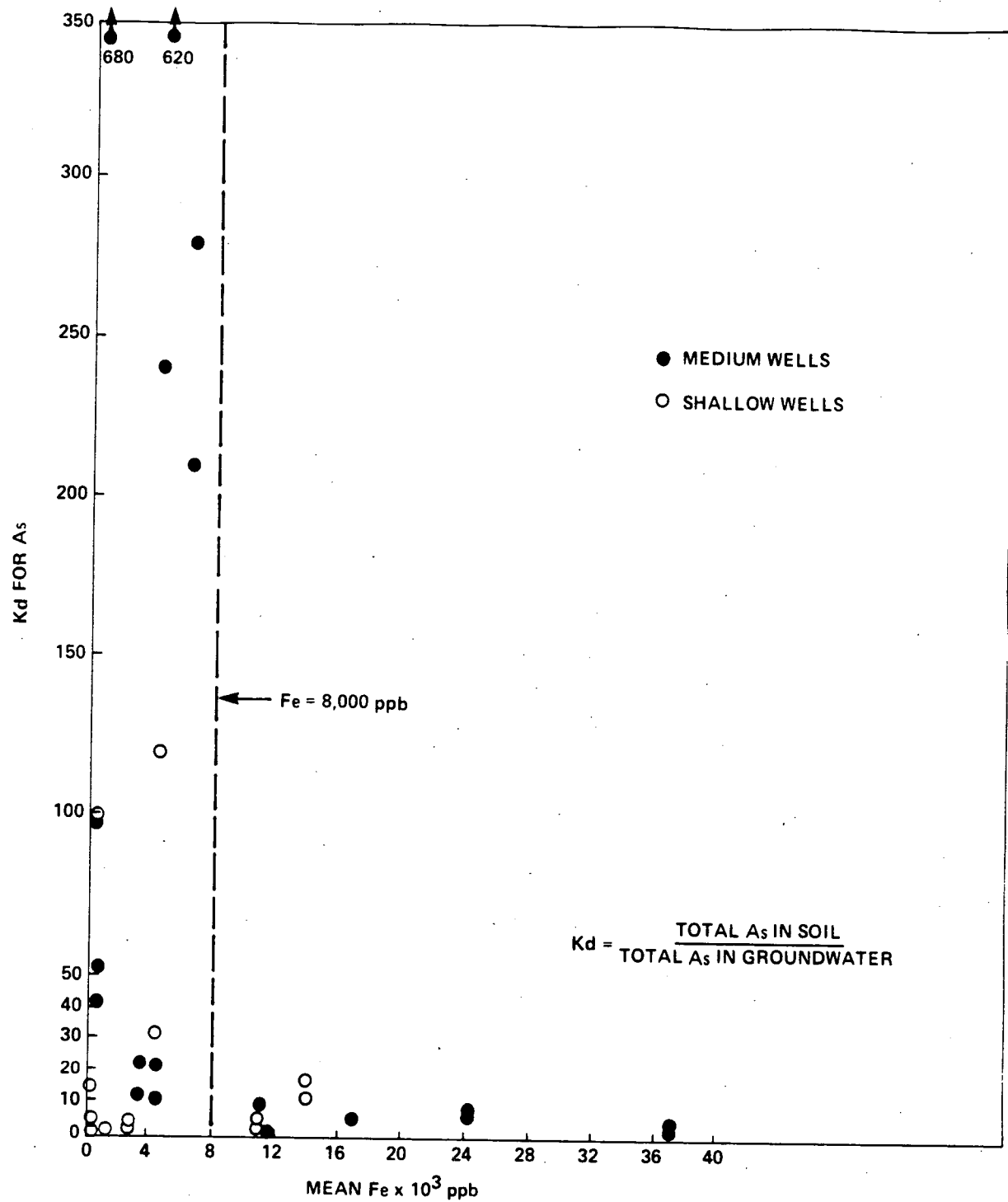
VINELAND CHEMICAL COMPANY SITE

FIGURE 5-5a

K_d VALUES FOR As vs. MEAN DISSOLVED
As CONCENTRATION IN GROUNDWATER
IN MEDIUM AND SHALLOW WELLS

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FIGURE 5-5b

Kd VALUES FOR As vs. MEAN TOTAL
IRON CONCENTRATION IN GROUNDWATER
IN MEDIUM AND SHALLOW WELLS

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The Kds can be used to estimate soil arsenic cleanup levels. Because the Kd describes the quantities of a substance which will partition between the solids and water, the concentration of the contaminant that can remain in the solid phase can be calculated if the Kd and the desired arsenic contamination is known. This is significant in terms of potential remedial actions.

Table 4-3 presents the mean and maximum background concentration of arsenic in soils on site as 2 and 5 mg/kg, respectively. The value of 2 mg/kg was obtained by averaging the soil arsenic concentration of well boring EW-1 (full boring), the soil arsenic concentration of well boring EW-9 (below the water table), and the soil arsenic concentration of well boring EW-12 (except the top surface soil sample). The data were presented in Figures 2-8a, 2-8h, and 2-8k. The value of 5 mg/kg is presented as the maximum background concentration because this was the maximum detected value in this data set.

As a practical matter, it may be said that the background soil arsenic concentration on the ViChem plant site is essentially undetectable. This is evident from an examination of the surface soil samples in Figure 4-1, and the soil boring data in Figures 4-2 and 4-3. These figures show that a number of samples in noncontaminated areas have undetectable arsenic concentrations. The same is true of Figures 2-8a, 2-8h, and 2-8k, which show that a number of the well boring samples also had undetectable arsenic concentrations. Assigning a background value of 2 mg/kg is essentially an attempt to quantify the undetectable arsenic concentrations for comparison purposes. It should be pointed out that the CLP's Contract Required Detection Limit (CRDL) for arsenic is approximately 2 mg/kg. This is consistent with the value of 2 mg/kg presented above.

To calculate a cleanup level for the aquifer soil, the background soil arsenic concentration of 2 mg/kg can be used as a base, assuming this arsenic to be relatively unleachable. The Federal Primary Drinking Water Standard for arsenic is 50 ug/l, assuming that the arsenic is not irreversibly bound to the soils. With the Kd range of 6 to 10, the allowable arsenic soil concentration that can be left in the soil ranges from 2.4 to 2.6 mg/kg. This level of arsenic in the aquifer soils will yield an arsenic concentration in the water in equilibrium with the soils of 50 ug/l, assuming that arsenic is not irreversibly bound to the soils.

The calculation presented above must be considered in light of a number of factors. First, the water must be in equilibrium with the soils. This may be true below the water table, but in the unsaturated zone it is probably not true. Unsaturated soil

leaching would probably be less efficient than predicted by a K_d , allowing in effect a higher arsenic concentration to remain in the soils than predicted. Second, a concentration of 50 ug/l directly below a leached source area may be much lower at a distance from the source area because of adsorption onto the aquifer soils. A much higher soil arsenic concentration may be allowed if the concentration of arsenic at the receptor is desired to be 50 ug/l. Also, in terms of remedial actions, these low arsenic soil concentrations may not be reliably targeted for removal. Finally, this calculation assumes that all arsenic above background is leachable. This may not be the case. The results of a water extraction treatability study presented in Section 7 show that arsenic was removed from the soil sample down to 17 mg/kg. This test would be considered optimal leaching conditions, since the soil was completely saturated with water (200 g soil with 200 ml water).

Because of the uncertainties with calculating the desorption of arsenic off of the soils, and hence a soil cleanup level based on the desorption criteria, it is recommended that column leaching tests be performed. These tests would help determine the leaching rate of arsenic off the soils, and may establish a level below which arsenic will not leach off the soils, despite being present above background concentrations.

The low K_d values for the site do present some interesting conclusions. First, the arsenic is highly mobile. Second, desorption of arsenic from contaminated aquifer soils may control the length of the groundwater cleanup after the sources of arsenic to the aquifer are removed.

5.1.3 Arsenic in the Site Groundwater

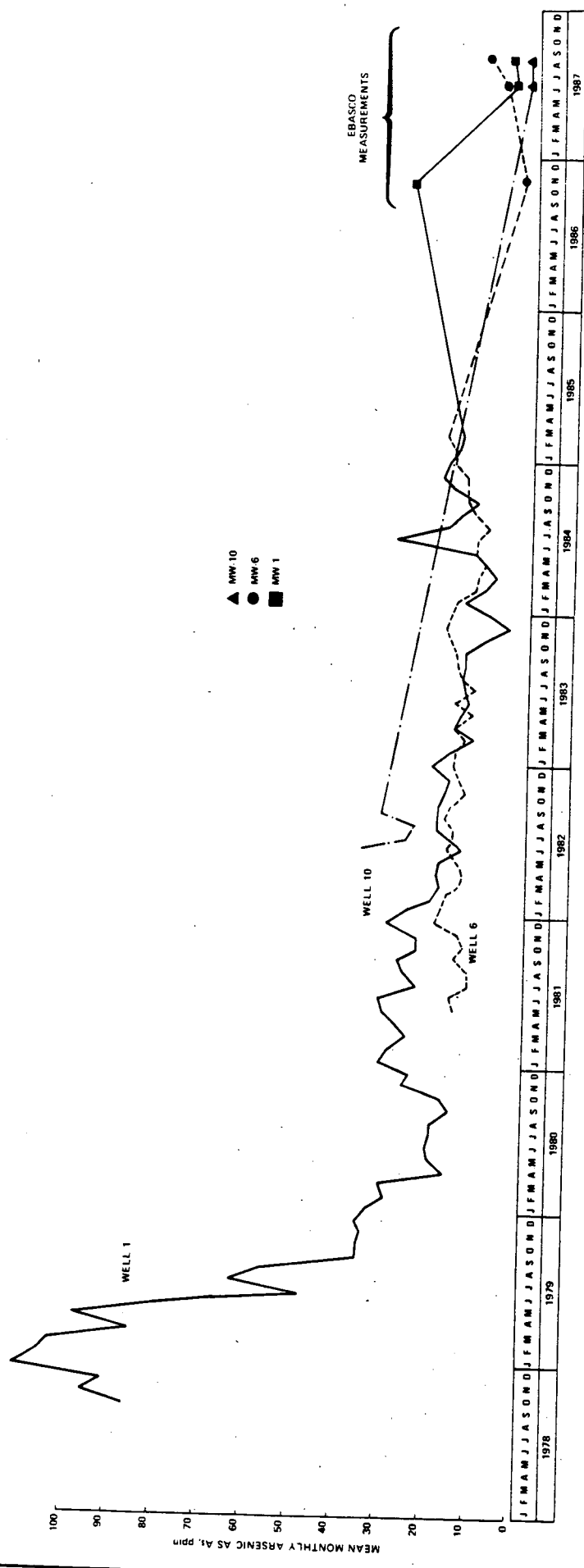
The irregular distribution of arsenic in the groundwater throughout the site along with the wide range of K_d values would suggest that the release rate of arsenic from the site has not been constant, nor has it always been in the same chemical form. Prior to 1978, raw materials containing arsenic and pesticide production wastes, contaminated with DMAA, MMAA and As_2O_3 were stored in large piles around the site. This material was left exposed to precipitation which dissolved it and carried it into the groundwater system. In addition, the lagoons used for wastewater were unlined and the wastewater was permitted to percolate into the groundwater. After 1978 these piles of raw and waste materials were removed and allegedly properly stored or disposed. In 1980, a wastewater processing plant was brought on line. A "pump and treat" groundwater cleanup system was also initiated. The most likely effects of these changes were to change the chemical nature of the arsenic released and to decrease the arsenic transport away from the site. This is a significantly different conclusion than that reached by Lennon and Johnson (1982), who suggested that the decrease was due to lower groundwater flow and recharge.

The distribution of arsenic in the groundwater from the medium wells shows an area with elevated concentrations at EW-4. This maximum is two orders of magnitude higher than the next closest measurement. There are several possible explanations for this. An unknown source of arsenic may exist northwest of the site, perhaps near the area now occupied by Martex Manufacturing, which is significantly higher than any measured on-site. In order to produce the difference between the surface and mid-depth samples at this well, however, this source would have to be very dense or it would have to be pumped to that depth. The groundwater at EW-4M does contain a very high level of sodium, but this level is not sufficient to create the kind of density difference necessary for the plume to sink through the aquifer without mixing significantly.

This maximum may represent the remainder of material produced prior to 1978. Since there was no treatment of wastes prior to that time, it would not be difficult to produce very high arsenic concentrations in groundwater. Data from studies conducted for ViChem by Lennon and Johnson (1982) and Woodward-Clyde (1985) show the trend in arsenic in the water from well MW-1 for a seven year period beginning in September, 1978 (see Figure 5-6). The validity of these data may be questionable since it is not clear how the data were collected and analyzed or who performed the analyses. The data show a sharp drop in the arsenic levels at monitoring well MW-1 from over 100,000 ug/l in December 1978 to 30,000 ug/l by March 1980. In addition, a slower downward trend is visible from August 1979 to March 1985, although it appears to have reached a constant level after 1982. It is likely that these trends are the result of the removal of the waste salt piles containing arsenic in 1978 and the later start-up and operation of the wastewater treatment plant, significantly lowering the flux of arsenic to the groundwater. It should be noted that the maximum concentration observed at MW-1 in December 1978 is only two to three times smaller than the value measured at EW-4M. It should also be noted that the monitoring wells MW-1, MW-6 and MW-10 were pumped as a result of a 1981 Administrative Consent Order with NJDEP.

The Ebasco measurements at MW-1, MW-6, and MW-10 are also plotted in Figure 5-6. These new values are consistent with the downward trends observed previously, although monitoring well MW-10 appears too low in 1987 relative to 1982.

The maximum at EW-4M may also be a result of dilution. The shallow groundwater may have been preferentially flushed by rainfall, which has had less of a dilution effect on the deeper groundwater. The deeper groundwater at EW-4M may represent the remnant of a highly contaminated plume that previously existed at the site. This highly contaminated plume is not observed in the shallow groundwater at EW-4S due to rainfall dilution.



NOTE: MONITORING WELLS 1, 6 AND 10 WERE PUMPED INTERMITTENTLY PRIOR TO THE 1981 ADMINISTRATIVE CONSENT ORDER WITH THE NJ DEP.

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VINELAND CHEMICAL COMPANY SITE
FIGURE 5-6 OBSERVED ARSENIC LEVELS IN MONITORING WELLS 1, 6, AND 10 VICHEM AND TRASCO MEASUREMENTS
TRASCO SERVICES INCORPORATED

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Hydrological models of the groundwater flow indicate that the transit time for water at the site to reach EW-4 is on the order of 5 to 15 years. Thus, the groundwater at EW-4 may be contaminated at levels similar to those found at the site near the lagoons 5 to 15 years ago. The effect of Kd will be to slow the movement of the arsenic maximum off site.

The shallow well arsenic concentrations shown in Figure 4-7 show widespread contamination with centers near each of the known major release centers; the site buildings, the lagoons, the hot spot area near the chicken coops, and the surface soil dump site. The lower levels between these centers are most likely due to dilution and groundwater flow. The medium well arsenic concentrations shown in Figure 4-8 show the impact of the largest and oldest sources, i.e., the lagoons and the site buildings. The contamination from the chicken coop area and the soil dump site apparently has not yet reached the deeper levels of the upper sand aquifer.

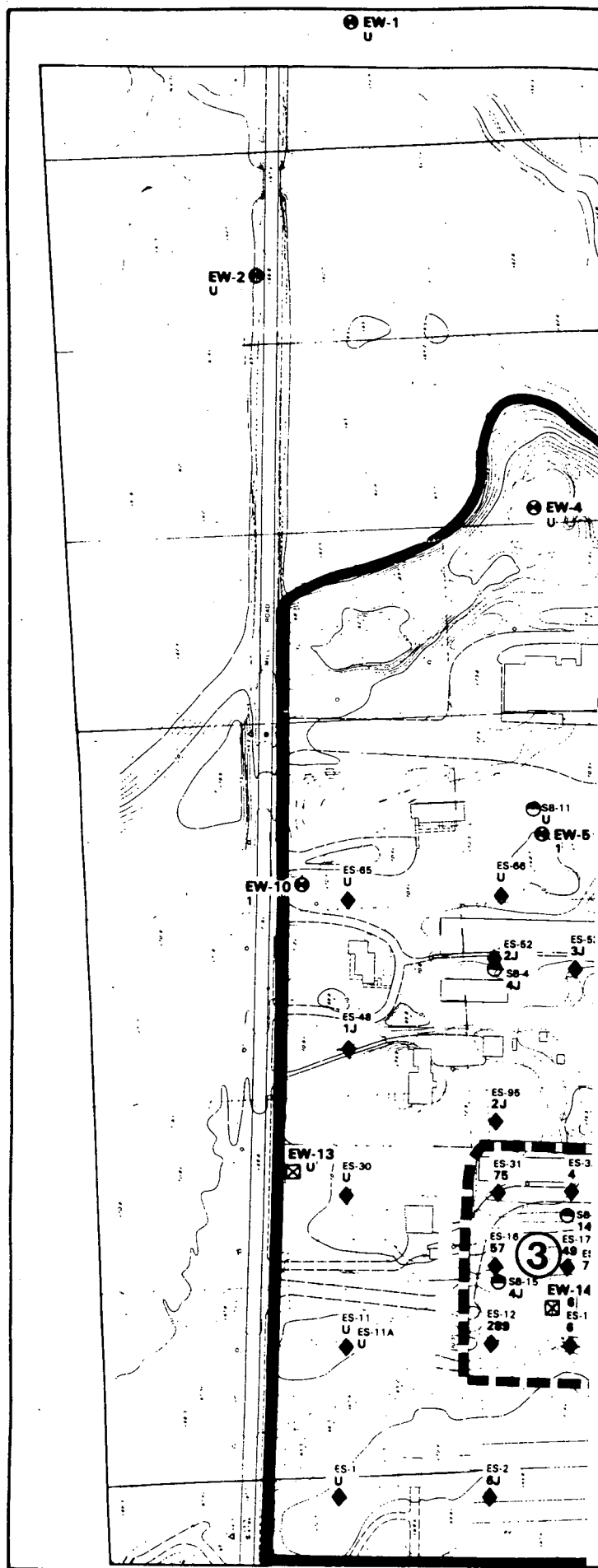
The arsenic levels measured in the groundwater from the deep wells show no significant levels above background, as shown in Figure 4-5. It would appear that the banded zone has prevented significant contamination of the lower aquifers.

5.1.4 Arsenic in the Surface Soils

The background levels of soil arsenic were established by examining the arsenic levels of the soils taken in wells EW-1 and EW-12 and the portion of well EW-9 below the water table as discussed previously. These wells appear to be sufficiently far from the contaminated areas to be free of any contamination related to the site. The background concentration was estimated to be 2 mg/kg, which essentially corresponds to the detection limit of arsenic in soils. The standard deviation in the data set analyzed was 0.4 mg/kg. This value agrees with the surface soil samples from the eastern edge of the site, which also appears to be free of contamination. It also falls at the lower end of the range of arsenic levels in sandy U.S. soil (see Table 4-3).

The distribution of arsenic on the surface soils shows several areas of high concentrations including the site buildings, the lagoon area, the service road, the hot spot area near the chicken coops and the backfill area near EW-15 (see Figure 5-7). The arsenic at these sites is usually concentrated in the top six feet of soil, probably the result of spills or dumping at each location with subsequent transport by percolation. The mean concentration in the top six feet at each area is given in Table 5-3. Below six feet, the soils are usually at background levels except only the most contaminated points. The total soil arsenic inventory including background for these areas is 2.3 to 9.6 metric tons, depending on whether the area-weighted

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- U = UNDETECTED
- ! = ESTIMATED VALUE
- J = VALUE BETWEEN CROD AND IDL
- X = REJECTED DATA
- F = FILTERED
- ⊕ TRIPLE WELL CLUSTER (8)
- ⊗ DOUBLE WELL CLUSTER (6)
- ⊙ STREAM GAUGE STATIONS
- ▲ EXISTING MONITORING WELLS (11)
- PRODUCTION WELL (1)
- HART (1)
- ◆ SURFACE SOIL SAMPLING LOCATIONS
- SOIL BORING LOCATIONS

SITE BOUNDARY USED FOR CALCULATION OF AQUIFER INVENTORY OF ARSENIC.

AREA BOUNDARIES FOR ELEVATED SURFACE SOIL LEVELS. THESE ARE THE AREAS USED TO CALCULATE THE SURFACE RUNOFF, PERCOLATION AND GAS EXCHANGE FLUXES. AREA NUMBERS REFER TO TABLE 5-3.

SCALE IN FEET
0 100 200

TOPOGRAPHIC BASE PREPARED FOR U.S. ARMY CORPS OF ENGINEERS BY KUCERA INTERNATIONAL, JANUARY 1986.

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FIGURE 5-7

LOCATION OF SURFACE AREAS USED IN INVENTORY CALCULATIONS

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TABLE 5-3

MEAN SOIL As CONCENTRATIONS
UPPER SIX FEET

<u>Area</u>	<u>Geometric</u> <u>Mean Soil As</u> (mg/kg)	<u>Arithmetic</u> <u>Mean Soil As</u> (mg/kg)	<u>Surface Area</u> (10 ³ ft ²)
1. Site Bldg Area	21.5	31.4	105
2. Lagoon Area	11.6	79.9	216
3. Hot Spots Area	13.2	46.2	33.7
4. Service Road	23.6	74.2	32.5
5. Backfill Area	<u>30.9</u>	<u>110</u>	<u>11.8</u>
Area Weighted Geometric Mean	= 15.9		
Area Weighted Arithmetic Mean	=	64.7	
Total Area	=		399,000 ft ²

Note: The final area weighted means were calculated on a strict area basis for both the geometric and arithmetic means. The area numbers refer to Figure 5-7.

geometric or the arithmetic mean is used, respectively. Excluding background, the anthropogenic arsenic inventory ranges from 2 to 9.3 metric tons.

The wide discrepancy between the geometric and arithmetic means in Table 5-3 is the result of the sample distribution. Highly contaminated, very localized zones of contamination exist within each area, with the majority of the area at or near background levels. This heterogeneity makes it difficult to reliably estimate the quantity of contaminated soil at the site.

5.1.5 Arsenic in the Aquifer Soils

The mean arsenic soils concentrations in the aquifer soils are listed in Table 5-4. The soil arsenic concentration above the banded zone is compared with that below, demonstrating that the banded zone effectively prevents contamination of the lower aquifer in most areas. The background soil level (2 mg/kg) was calculated from Ebasco wells EW-1, EW-9 and EW-12 as previously discussed. The soils from all other wells show arsenic concentrations at least 2 to 30 times higher than this. Well EW-10 is similar to the background levels although it does show some low grade contamination. The distribution of arsenic appears to change with distance from the lagoon areas. The broad contamination distribution in Well EW-7 appears only as a high narrow band in wells EW-2 and EW-4 (see Figure 2-8). The reason for this, although unclear, is probably a result of groundwater flow, variations in site output, and exchange with the stream at sites EW-2 and EW-4.

The mean arsenic concentration in the aquifer soils for the area defined by the stream flood plain edge, Mill Road, the southern site boundary and the north-south running road at the east side of the property (approximately 44.8 acres) is 6.65 to 10.7 mg/kg on a dry weight basis (geometric and arithmetic means, respectively) (see Figure 5-7). This excludes wells EW-1, EW-9 and EW-12. The total arsenic within the aquifer from the water table to the top of the banded zone is approximately 34 to 55 metric tons, of which 10 metric tons result from background concentrations and the remainder are the result of contamination. This inventory includes both the arsenic bound to the soil and the arsenic dissolved in the groundwater. It should be noted that the 24 to 45 tons of additional arsenic are much more mobile than the background-related arsenic, based on the variation of K_d with arsenic concentration (see Figure 5-5a).

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1120

TABLE 5-4

SATURATED SOIL ARSENIC LEVELS
(Water Table Aquifer)

<u>Ebasco</u> <u>Well</u>	<u>As</u> <u>Water</u> <u>Table to</u> <u>Banded</u> <u>Clay</u> (mg/kg)	<u>As</u> <u>Below</u> <u>Clay</u> <u>Layer</u> (mg/kg)	<u>Depth of</u> <u>As Maximum</u> (feet)	<u>Maximum</u> <u>As</u> <u>Concen-</u> <u>tration</u> (mg/kg)	<u>Top of</u> <u>Banded</u> <u>Clay Layer</u> (feet)
1	(1.6)U	U	None	U	38
2	8.4	U	30	133	48
4	10.2	U	50	482	45
5	4.8	2	40	17.6	48
6	4.4	-	40	41.2	58
7	49.8	11.4	60	209	60
8	15.4	-	30	60	70
9	0.64	4	25	5.98	73
10	1.4	U	35	8.5	40
11	10.4	-	60	24	65
12	(1.6)U	-	None	U	70
13	6.0	-	30	20.5	50
14	2.2	-	30	11	55
15	4.2	2.1	25	20	70

As Geometric mean of saturated soils above clay layer = 6.65*

As Arithmetic mean of saturated soils above clay layer = 10.7*

* Excluding EW-1, EW-9, EW-12

U - Below detection limits

- - No samples taken

VIN 001 1121

5.1.6 Transport of Arsenic Away from the Site

There are three potential pathways for arsenic transport from the site. These include groundwater transport, surface runoff, and gas transfer.

The gas transfer of arsenic occurs via biological conversion of arsenic-organic to volatile forms. The study by Woolson and Kearny (1972) suggests that up to 35% of the arsenic in the form of cacodyllic acid (dimethylarsenic acid) could be released this way under aerobic soil conditions in a period of 24 weeks. The exact percentage of cacodyllic acid in the waste is unknown. However, the normal waste from the production of this acid (one of the products from ViChem) contains 1 to 2% cacodyllic acid (Sittig, 1980). The present wastes, largely liquid, contain arsenic as sodium monomethyl arsenate (M&M Engineers, 1978) for which the biological conversion rate to volatiles is unknown.

As a worst case, if all soil arsenic were in the form of cacodyllic acid, the gas flux from the top two feet of the contaminated areas listed in Table 5-3 would be 2.5 kg/day (913 kg/yr) or 6.25 mg/day-ft². This, however, would quickly deplete the soils. As unlikely a scenario as this is, no other data exist more accurately estimating the flux.

A more likely vehicle for transport of arsenic off site is surface runoff, which may remove arsenic in both dissolved and particulate form. Using the highly contaminated areas on site (399,000 sq ft), a mean soil arsenic concentration of 16 to 65 mg/kg (Table 5-4), and a net sediment transport rate for this drainage area of 0.056 gm/ft²-yr (194 ton/yr per 113 sq mi, Lennon & Johnson, 1982) yields a sediment-bound arsenic transport of 0.35 to 1.4 gm/yr. If equilibrium between runoff water and the surface soils is assumed, then with a K_d of 6 to 10 and 22% of annual precipitation (44 inches) appearing as surface runoff, the total transport becomes 14 to 98 kg/yr.

The groundwater flux involves the input of arsenic to the groundwater and the outflow of arsenic from the groundwater to the receiving stream, the Blackwater Branch. The input of arsenic to the groundwater can come from percolation of rainfall that has leached arsenic from contaminated soils and from the treatment plant discharge. The outflow of arsenic can be derived by estimating the groundwater flow from the site and the average concentration of arsenic in the groundwater, then using those to calculate the total mass of arsenic leaving the site. As a cross check, the amount of arsenic leaving the site can be estimated by determining the total load of arsenic in the Blackwater Branch and comparing this amount with the load calculated from the groundwater.

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The amount of arsenic percolating into the groundwater from arsenic-contaminated soils can be calculated using the regional precipitation (44 inches/year), the amount of precipitation that recharges the groundwater (26%), the mean arsenic concentration in the contaminated soil areas (16 to 65 mg/kg), and the K_d (6 to 10 l/kg). The percolation of arsenic into the groundwater calculated this way is 0.043 to 0.30 grams of As/yr-ft² for all of the contaminated areas, or 17 to 115 kg of arsenic per year.

Another source of arsenic into the groundwater is the percolation of the treatment plant effluent from unlined lagoon UL-A. Reportedly, the treatment plant produces approximately 7,540,000 gallons of discharge per year with a maximum arsenic concentration of 0.7 mg/l (Woodward-Clyde, 1985). This would represent an additional 19 kg/year of arsenic entering the groundwater. If the treatment plant is more efficient and the arsenic concentration is lower (e.g., 0.05 mg/l), this load would be even less (1.4 kg/year).

Summing the two inputs described above yields a present-day input rate of 36 to 134 kg/year of arsenic entering the groundwater. Past practices probably resulted in significantly greater inputs of arsenic to the groundwater system prior to the time wastes were properly containerized or treated.

The amount of arsenic leaving the site via groundwater outflow can be calculated by determining the groundwater outflow and applying the average concentration of arsenic in the groundwater. Calculations using the data collected in this RI are shown in Table 5-5.

The groundwater outflow along each of the three groundwater flow vectors presented in Section 3 was determined. The arsenic load along each of these vectors was estimated by averaging the arsenic concentrations in the shallow and medium depth wells closest to the site boundaries. Averages were calculated in both the arithmetic and geometric forms. All of these data are from the upper sand aquifer.

The calculations show that the total arsenic flux off the site via the groundwater in the upper sand aquifer is estimated to be 1.2 to 11 metric tons per year (1,200 to 11,000 kg/year). This is significantly higher than the present-day arsenic input calculated previously.

TABLE 5-5

ARSENIC TRANSPORT AT THE SITEBlackwater Branch Transport

<u>Location</u>	<u>Flow</u> (m ³ /s)	<u>Total As</u> (ug/l)	<u>Flux</u> metric tons/yr
ER-2, 1987 (stream background)		2.5 (U)	
ER-4, 1987	0.91	153	4.3
ER-5, 1987	0.47	570	8.2
Lennon & Johnson, 1982	0.30	1,000 (background [As] = 300 at 0.29m ³ /s)	6.8 (9.6 at ER-3 -2.8 at ER-2 = 6.8)

Groundwater Transport to Blackwater Branch

<u>Vector*</u>	<u>Flow*</u> (m ³ /s)	<u>Wells</u> EW	<u>[As]</u> Arithmetic Mean (ug/l)	<u>[As]</u> Geom Mean (ug/l)	<u>Flux</u> Arithmetic Geom (As Metric Tons/Yr)	
1	6.8x10 ⁻³	10+13	528	257	0.11	0.055
2	3.5x10 ⁻³	2+4	79,900	2860	8.8	0.32
3	0.0114	7+8	5740	1970	<u>2.1</u>	<u>0.71</u>
Total Groundwater As Transport					11.0	1.1

* From Table 3.5

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Another method to estimate the groundwater outflow off the site is to determine the arsenic load in the Blackwater Branch upstream and downstream of the site. The difference in the arsenic load between the two can be assumed to result from groundwater discharge off the site. If all of the groundwater from the site enters the surface water, then the groundwater arsenic flux and the surface water arsenic flux should match fairly well.

Table 5-5 presents the arsenic loads calculated from data taken in the Blackwater Branch during this RI. At station ER-2, upstream of the site, the arsenic concentration in the Blackwater Branch was undetected (detection limit 2.5 ug/l). At ER-4, downstream from the site at the Mill Road bridge, the arsenic concentration was 153 ug/l with a flow of 32.3 cfs. The net arsenic load added to the stream is the difference between the two concentrations times the flow rate. This calculates to be 4.3 metric tons per year (4,300 kg/year), which is in agreement with the groundwater estimates presented previously.

Station ER-5 is approximately 4,000 feet further downstream from station ER-4 on the Blackwater Branch. Using the arsenic concentration measured here of 570 ug/l at a flow of 16.5 cfs, the total arsenic load passing this point is 8.2 metric tons per year. This is in agreement with the values for ER-4, even though the stations were sampled on different days, and is in agreement with the calculated groundwater fluxes.

Both stations ER-4 and ER-5 integrate long distances of the stream bed and probably accurately reflect the arsenic flux from the site to the stream. There is not enough sensitivity in the data to state definitely whether the arsenic load at ER-5 is genuinely higher than at ER-4. At a minimum it is possible to say that the arsenic load in the Blackwater Branch closely approximates the load calculated from the groundwater outflow, indicating that the arsenic in this stream is a result of groundwater discharge from the site.

The arsenic outflow off the site was estimated by Lennon and Johnson in a 1982 study conducted for ViChem. Using the flow and arsenic concentrations in the Blackwater Branch measured upstream and downstream of station ER-3A (before the beaver dam was built), they calculated an arsenic load of 6.8 metric tons/year (i.e., the difference between their upstream flux of 2.8 metric tons per year and the downstream flux of 9.6 metric tons/year). Assuming a groundwater flow rate off the site of 0.2 cfs in the vicinity of ER-3A, they estimated an average arsenic concentration in the groundwater entering the stream of 38,000 ug/l. It should be noted that these investigators did not obtain samples well upstream from the entire site as wa

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done in this RI. Given the low stream levels measured by Ebasco at ER1 and ER2, it is highly likely that the total downstream flux measured by Lennon & Johnson of 9.6 metric tons/yr is the more representative site arsenic input in 1982.

These 1982 estimates are in agreement with the values calculated using Ebasco's 1987 data. This suggests the possibility that the arsenic flux to the Blackwater Branch may have been relatively constant from 1982 to 1987. There is not enough precision in the stream flow flux measurements to state whether or not this is so. However, Figure 5-6 shows relatively constant arsenic concentrations in ViChem monitoring wells MW-1, MW-6, and MW-11 from 1982 to 1987.

ViChem has operated a groundwater treatment plant at the site since approximately 1980. Using the average arsenic concentration in ViChem wells MW-1, MW-6 and MW-11 between 1982 and 1985 of approximately 15,000 ug/l, this calculates to an arsenic removal rate of 0.3 metric tons of arsenic per year. This is an insignificant rate compared with the arsenic flux from the site based on groundwater advection.

The calculated present day arsenic flux from the site is summarized in Table 5-6. The estimated fluxes from the site range from approximately 1.2 to 11 metric tons per year. Of these, it is felt that the most representative flux estimate is approximately 6 metric tons per year.

The calculated arsenic flux from the site is far less than the input estimated from the percolation of arsenic from contaminated soils and from the treatment plant discharge. There are two possible reasons for this. First, there is a significant amount of arsenic bound to the saturated aquifer soils which at K_d 's of 6 to 10 will maintain a high concentration of arsenic in the groundwater, hence a continual arsenic flux from the site. This arsenic would represent earlier releases which have built up in the aquifer soils. Second, the treatment plant discharge may not have as low an arsenic concentration as reported.

The total quantity of available arsenic in the aquifer was presented previously as being approximately 24 to 45 metric tons based on the average soil arsenic concentrations below the water table and the K_d (excluding the estimated 10 metric tons of background arsenic). This arsenic may leach from the soils into the groundwater and maintain elevated groundwater levels even if no additional arsenic is added to the system.

A groundwater model was prepared for the Plant Site FS (Ebasco 1989b) to evaluate various groundwater pump and treat scenarios. This model is discussed in detail in that document along with the effects of various pump and treat scenarios remediating the contaminated groundwater. It is important to note here, however, that one of the parameters calculated by the model is the time to naturally flush the arsenic from groundwater.

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TABLE 5-6

ESTIMATED ARSENIC FLUXES AT THE SITE
DURING 1986-1987

<u>MECHANISM</u>	<u>ARSENIC TRANSPORT</u> (metric tons/yr)
INFLOW	
Treatment Plant Discharge	0.02
Surface Water Percolation	0.02 to 0.12
OUTFLOW	
Gas Transfer*	0.91
Surface Water Runoff	0.01 to 0.10
Groundwater Flow**	1.2 to 11
Stream Flow**	4.3 to 8.2
Groundwater Treatment***	0.3

*This estimate is included only for comparison since its error limits are completely unknown.

**These two fluxes represent essentially independent estimates of the same flux, i.e., groundwater arsenic transport and thus, should be equal. The calculated ranges suggest this to be so.

***This process was shut down in 1987.

Table 5-7 presents the time it is predicted for the arsenic concentration to decrease below 50 ug/l in the groundwater assuming that no additional arsenic is added to the system, and assuming that no pumping/treatment is undertaken to promote the flushing. The table shows that the natural flushing rate is highly dependent on the K_d of arsenic. Assuming the lowest mean K_d presented above, 6.6 l/kg, it is predicted that over 500 years will be required for the arsenic concentration in the contaminated upper sand aquifer to fall below 50 ug/l naturally.

Two of the assumptions in the groundwater model are that the aquifer soils and the groundwater will always be in equilibrium, and that the K_d is constant, i.e., that the K_d does not change as the concentration of arsenic on the soils and groundwater change. Evidence presented in this section suggests that arsenic's K_d may not remain constant and may in fact increase at low soil arsenic concentrations. This may mean that not all arsenic will desorb off the aquifer soils. Instead, a point may be reached at which arsenic will not desorb further from the aquifer soils. This would reduce the predicted natural flushing rates considerably.

It is not possible to predict the concentration below which arsenic will stop desorbing off of the soils with the existing data base. A soil washing treatability study presented in Section 7 shows that the arsenic concentration of one sample was reduced from 114 to 17 mg/kg; however, it is not known if additional washing could have produced a lower concentration. Column leaching tests are recommended in Section 8 to provide additional data on arsenic's desorption characteristics, and to aid in determining if there is a point below which arsenic will not desorb off of the site soils.

5.2 CADMIUM

5.2.1 Geochemistry of Cadmium

Cadmium (Cd) is present in soils at concentrations of from 0.01 to 7.0 mg/kg. Cadmium is mobile in the environment. It may be transported from soils as soluble cadmium salts, as the hydrated cation, or as organic or inorganic complexes in the aquatic environment. Under natural conditions cadmium exists almost exclusively in the +2 valence state (Callahan et al., 1979).

Aqueous Speciation

In natural waters dissolved cadmium may exist as a simple ionic species, or as part of an inorganic or organic complex. Equilibrium model calculations performed by Turner et al. (1981) indicate that at representative natural water concentrations of the principal inorganic dissolved cadmium complexing agents (carbonate, sulfate, chloride and fluoride = $10^{-4}M$), the principal aqueous inorganic cadmium species at pH 6.0 should be Cd^{2+} , with small amounts (5%) of the aqueous phase cadmium being present as $CdSO_4^0$ and $CdCl^+$. At pH 9.0, equilibrium

TABLE 5-7

PREDICTED TIMES TO ACHIEVE A 50 ug/l ARSENIC
CONCENTRATION IN THE CONTAMINATED
UPPER SAND AQUIFER VIA NATURAL FLUSHING

<u>Kd</u>	<u>Time to Achieve 50 ug/l¹ Arsenic Concentration</u>
0.2	25 yrs
3.3	250 yrs
6.6	500 yrs

¹ Taken from Plant Site FS report (Ebasco, 1989b). See this report, Appendix C, for complete presentation of model assumptions.

calculations indicate that Cd^{2+} and CdCO_3 should be the principal inorganic species with the aqueous phase cadmium concentration controlled by the solubility of solid phase cadmium carbonate (octavite). Solubility product calculations predict maximum aqueous phase cadmium concentrations in equilibrium with octavite to be about $1 \times 10^{-8} \text{M}$ (approximately 1 to 2 $\mu\text{g/l}$). Based on the pH range measured by Ebasco of 4.5 to 8.0 with a median of 5.9, the principle aqueous inorganic cadmium species should be Cd^{2+} , with approximately 5% as CdCl^+ and CdSO_4^0 .

The overall effect of dissolved organic matter on influencing aqueous phase cadmium speciation and concentrations is uncertain. Guy and Chakrabarti (1976) have shown that humic and fulvic acids can form dissolved complexes with cadmium as well as other trace metals (lead, copper, zinc, etc.). These authors have shown that such complexes might be a significant mechanism for cadmium remobilization from sediments to the water column. Conversely, in studies on Mississippi River sediment-water interactions, Khalid (1980) concluded that soluble organic ligands had little effect on aqueous phase cadmium concentrations, except at relatively high dissolved organic concentrations.

Given the clean sands of the upper aquifer at this site, these organic forms are probably not important. However, a related form of cadmium produced at the ViChem plant is potentially important.

Precipitation/Dissolution

Solid phase cadmium carbonate precipitates (principally CdCO_3 ; octavite) under alkaline conditions may control the maximum dissolved cadmium concentrations in at least some natural freshwaters (Jenne *et al.*, 1980). This apparent solubility control has been observed in certain mine waters in contact with soils of high cadmium concentration.

Adsorption/Desorption

Generally, adsorption reactions may be more important in controlling and removing heavy metals from the aqueous phase in natural waters than precipitation processes (Callahan *et al.*, 1979). They may, however, be relatively less important for cadmium as compared to precipitation.

Cadmium has been shown to be adsorbed by a variety of sediment solid phase components including hydrous iron, aluminum and manganese oxides, clays, soil organic matter and carbonate minerals. Disagreements exist, however, with respect to which sediment solid phases are most important in cadmium adsorption.

Gardiner (1974) showed that sediment adsorption of cadmium could be closely correlated with the neutral or slightly alkaline soil conditions. Cadmium adsorbed by sediments was associated with sediment organic matter. This cadmium was, however, reported to be labile and subject to reassociation with sediment inorganic phase exchange sites following solution phase pH decreases. The mechanism of labile cadmium release from soil organic phases as solution pH levels decrease is uncertain but may relate to hydrogen ion neutralization in the sediment organic phase. However, Rai and Zachara (1984) have concluded that the soil organic fraction does not demonstrate a marked affinity for cadmium and apparent cadmium adsorption by organics may reflect cation exchange processes.

The specific adsorption of cadmium to calcite and hydrous oxides of aluminum and iron may be the most important adsorption mechanism at "environmental concentrations of cadmium". Evidence cited by Rai and Zachara (1984) includes observations that clay minerals with adsorbed humic acid do not demonstrate significantly increased cadmium adsorption when compared to the same clays in the absence of humic acid (Levy and Francis, 1976).

In recent examinations of cadmium partitioning in soils and sediments, Hickey and Kittrick (1984) reported that cadmium appears to be primarily associated with exchangeable carbonate, and Fe-Mn oxide solid phases. The results of these selective extraction studies indicated soil and sediment organic fractions to be relatively unimportant in cadmium binding. The high exchangeable cadmium fraction reported in these previous studies suggests that cadmium is a relatively bioavailable trace metal.

The adsorption of cadmium by soils and sediments is influenced by a number of environmental chemical factors including solution pH, solution composition and soil cation exchange capacity. In general, increasing solution pH levels will increase cadmium adsorption by increasing the negative charge on sediment solid phases. Increasing solution ionic strength, particularly when reflecting increasing calcium and magnesium concentrations, decreases cadmium adsorption through competition for solid phase cation exchange sites.

Partitioning to Sediments

The principal processes affecting cadmium mobility in natural waters are partitioning to soil, bottom sediments and suspended solids in the water column through adsorption and/or precipitation mechanisms. Evidence suggests that adsorption to sediment hydrous oxides, mineral phases and, to a lesser extent, sediment organic fractions will be the three predominant partitioning mechanisms.

Partitioning to sediments through adsorption processes is likely to be more reversible than partitioning processes involving precipitation. Desorption from sediments to the aqueous phase will occur under certain aqueous phase chemical conditions, such as during sudden decreases in aqueous phase cadmium concentrations (a change in equilibrium), increases in solution ionic strength (competition for adsorption sites), decreases in solution pH (neutralization of surface charge) or a combination of these.

5.2.2 Cadmium at the ViChem Site

Cadmium was detected in the groundwater of the water table aquifer at concentrations of 0-305 ug/l. Cadmium was not detected in the subsurface soils. This yields a calculated K_d of zero as compared to the literature values in Table 5-8. A probable cause for the lack of cadmium on the soil is the competition with As III and As V for the cation exchange sites on the soil solids surface. However, the possibility of a related form of cadmium produced at the chemical plant cannot be ruled out.

In either case, with the lack of partitioning to the soil, cadmium most likely will be quickly carried away from the site by the groundwater. This is supported by the large increase in cadmium levels in the monitoring wells between July and September 1987. This behavior is typical of a compound with a low K_d . Using the groundwater fluxes calculated in the Section 3.4, a cadmium flux away from the site can be calculated.

The flux of cadmium to the stream was calculated for each of the flow vectors (see Table 5-9) using the appropriate wells to calculate the cadmium concentration. This flux is probably a conservative estimate since the wells used do not have the highest cadmium concentrations on the site. Thus, the cadmium flux can be expected to increase in the short term. The total cadmium flux from the site at present is estimated to be 53.4 to 379 kg of cadmium per year. Note that only the concentrations from September 1987 were used for this calculation. Nearly all the appropriate wells had near nondetected values for the July samples.

The cadmium transported by groundwater to the stream will most likely be immediately bound to the stream sediment or to the suspended matter and end up in the bottom sediments of the stream. These materials tend to be more reactive, with a higher organic matter fraction and greater surface area than aquifer soils and are therefore more efficient at absorbing cadmium.

TABLE 5-8
Kd VALUES FOR CADMIUM

<u>Kd</u> (l/kg)	<u>Source</u>
1.7 x 10 ⁴	Hudson River sediments at Foundry Cove, from Deck, 1981.
2-10 x 10 ⁴	Hudson River suspended matter based on Klinkhammer, 1978; from Deck, 1981.
(0.03-30) x 10 ⁴	Personal discussion with D. Toro, 1986.

TABLE 5-9

Cd TRANSPORT AT SITE

Groundwater Transport to Blackwater Branch

<u>Vector</u>	<u>Flow</u> (m ³ /s)	<u>Wells</u> EW	<u>[Cd]*</u> Arithmetic Mean (ug/l)	<u>[Cd]*</u> Geom Mean (ug/l)	<u>Flux</u>	
					Arithmetic (Kg Cd/yr)	Geom
1	6.8x10 ⁻³	10+13	24	14	5.1	3.0
2	3.5x10 ⁻³	2+4	2440	165	270	18
3	0.0114	7+8	288	90	<u>1040</u>	<u>324</u>
Total Cd Flux					379	53.4

* These values are based on the September measurements only.

The surface transport of cadmium, unlike arsenic, is probably insignificant since no surface soil concentrations of cadmium were found. No cadmium was found in the lagoon waters or sediments (no leachable cadmium was found during the EP Toxicity test of the lagoon sediments) nor in the stream and its sediments. This would suggest that the cadmium in the groundwater represents a short term release which is no longer occurring and has not yet reached the stream. This release has been completely leached from the surface soils of the site as well. The distribution of cadmium in the groundwater suggests that it was associated with the waste storage piles and lagoons which existed over the two cadmium concentration maximas.

5.3 MERCURY

5.3.1 Geochemistry of Mercury

Mercury exists in the natural environment in three oxidation states: as the native element itself, in the +1 (mercurous) state, and in the +2 (mercuric) state. The nature of the species which will occur in a given assemblage or will predominate in solution depends upon the redox potential and pH of the environment. The solubility of metallic mercury in pure water has been determined by Sanemasa (1975) to be 19.2 ug/l and 81.3 ug/l at 5°C and 30°C, respectively.

The abundance of mercury in the earth's crust is difficult to estimate. Fleischer (1970) reported that concentrations vary between 5 and 1000 ug/kg in common natural materials. Considerably higher concentrations have been measured in specific formations in mercury-rich regions of the world. Erickson (1960) estimated that about 10^{10} metric tons of rock are weathered each year worldwide. Using an average mercury content for rocks of 80 ug/kg, this would mean that about 800 metric tons of mercury are released from rock every year. Since typical soils do not contain higher concentrations of mercury than the underlying rock, some of this weathered mercury must reach the aquatic environment. The mean mercury levels in U.S. sandy soils is 0.01 to 0.54 mg/kg (Kabata-Pendias and Pendias, 1984).

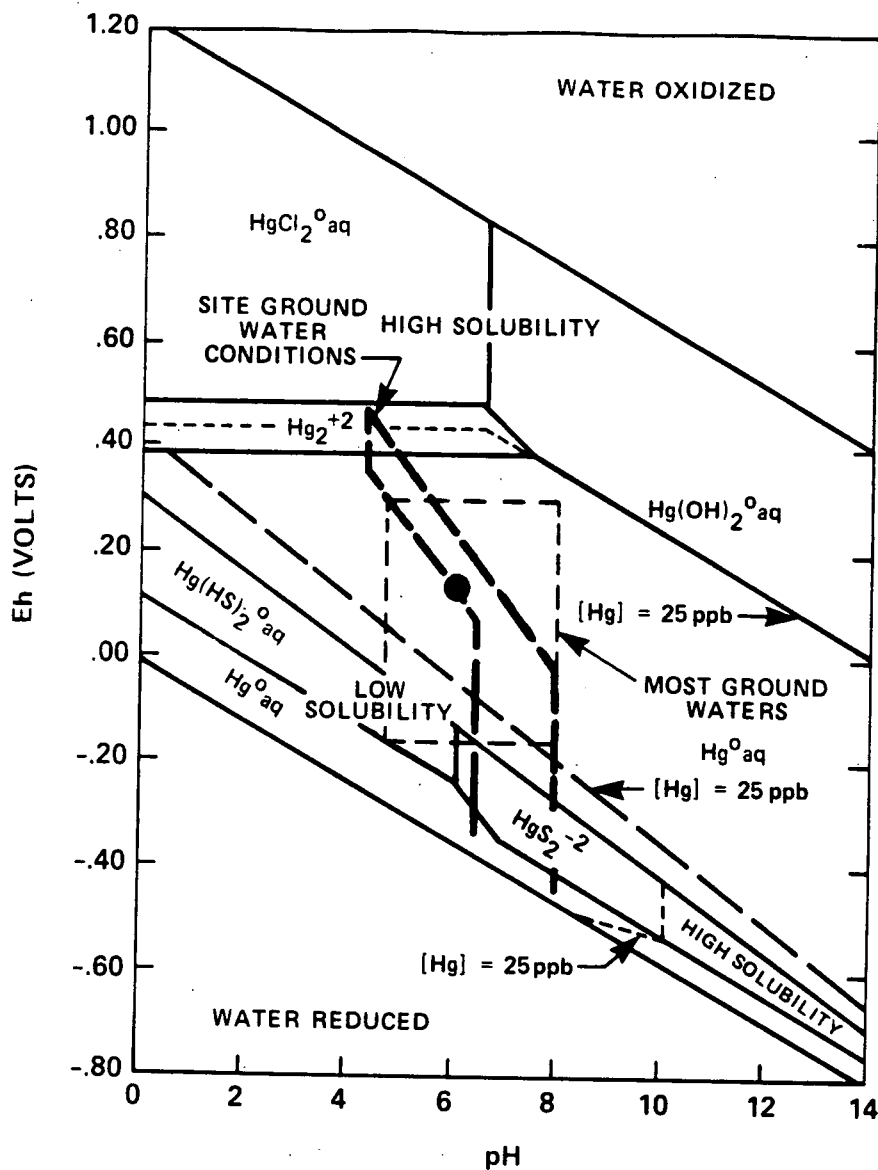
Mercury is released into the air by outgassing of soil, by transpiration and decay of vegetation, and by volatilization and combustion processes. Most mercury is adsorbed onto atmospheric particulate matter. This is removed from air by dry fallout and rainout. Humic material forms complexes that are adsorbed onto alluvium, and only a small soluble fraction is taken up by biota. Small clay particles and rainout particles are distributed throughout the oceans because of slow settling velocities. Pelagic organisms agglomerate the mercury bearing clay particles, thus promoting sedimentation and affecting the fate of mercury in mid-oceanic chain. Another fate process is the uptake of dissolved mercury by phytoplankton and algae.

A typical E_h -pH diagram for the predominance of mercury species is presented in the paper by Gavis and Ferguson (1972) in which only the inorganic system is considered. In natural water systems, where pH is likely to fall between 6 and 9 and the measured E_h values seldom are higher than 0.5v, metallic mercury Hg^0 and HgS are the species most likely to enter into equilibrium with mercury species in solution. The E_h -pH diagram for the soluble species in equilibrium with the solids phase shows that $Hg(OH)_2$ and $HgCl_2$ are the predominant species in most surface waters.

At low redox potentials observed in reducing sediments, mercury is effectively immobilized by sulfide ion. At extremely low redox potential and pH greater than 9, the solubility increases markedly by the formation of HgS_2^{2-} ions. The stability field for aqueous mercury constructed by Stolzenburg et al. (1986) is shown in Figure 5-8. Bartlett and Craig (1981) have summarized mercury chemistry over a wide range of redox conditions within the sediment. Fagerstrom and Jernelov (1972) and others have reported that the rate or extent of mercury methylation is increased when sediments are exposed to air, e.g., on dredging or during ebb tide.

Two types of alkylated mercury compounds are formed in the environment. In compounds with a single carbon-mercury bond, the compound acts as a substituted salt and is reasonably water-soluble. An example is methyl mercuric chloride (CH_3HgCl) which becomes CH_3Hg^+ ion and Cl^- ion in solution. The other type involves covalent attachment of two carbon atoms to the mercury. Although they are considered insoluble, dialkyl, covalent mercury compounds may appear in natural waters at trace levels. An example is dimethyl mercury (CH_3HgCH_3) which is volatile and is undissociated in solution. The chemistry of methyl mercury species and equilibria in aqueous solution have been discussed in detail by Burrows et al. (1974) and Rabenstein et al. (1975).

Methyl mercury is produced in sediments by bacteria through the methylation of inorganic mercury (Hg^{2+}) (Spangler et al., 1973). Two types of methylation are possible: microbial (enzymatic) and chemical (non-enzymatic by methylcobalamine). They have noted the presence of bacteria capable of degrading methyl mercury to methane and Hg^0 which volatilizes and escapes into the atmosphere. The rate is higher with suspended material and in the surficial sediment rather than deep sediment (Jernelov, 1970). Formation of dimethyl mercury is not favored in acidic environments (Gavis and Ferguson, 1972), and the amount of dimethyl mercury formed is usually several orders of magnitude less than that of monomethyl mercury ion, CH_3Hg^+ . Fagerstrom and Jernelov (1972) reported the formation of both species in organic sediments at various pHs, with a maximum dimethyl mercury production at pH 9 and a maximum production of methyl mercury at pH 6.



Stability fields for aqueous mercury species at various Eh and pH values (chloride and sulfur concentrations of 1 mM each were used in the calculations) Common Eh-pH ranges for groundwater and the site are also shown.

● MEAN pH & Eh FOR THE SITE

FROM HEM, 1970.

U.S. ENVIRONMENTAL PROTECTION
AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 5-8
pH-Eh OXIDATION-REDUCTION
DIAGRAM FOR MERCURY
UNDER SITE CONDITIONS

EBASCO SERVICES INCORPORATED

VIN 001 1137

Lee et al. (1985) studied the catalytic effect of various metal ions on the methylation of mercury in the presence of humic acids (HA). This process may be important during the vertical transport of Hg from the surface to the water table. Methylmercury production (in dark reactions during 2 to 4 day incubations at 30°C) increased with the concentration of mercury ions and fluvic acid as well as with the addition of metal ions. Metal ions competitively reduced the Hg bonding with HA, thus freeing it for methylation. The observed catalytic activity of metal ions followed the order: $\text{Fe}^{3+} > \text{Fe}^{2+}, \text{Cu}^{2+}, \text{Mn}^{2+} > \text{Al}^{3+}$. The production of methyl mercury had a pH optimum of 4 to 4.5.

Bartlett and Craig (1981), from their study of the Mersey Estuary, noted a positive correlation between total mercury, methylmercury, silt and organic carbon. The greater the organic or silt content of the sediment, the higher the mercury content was per gram of sediment.

The proportion of methylmercury to the total amount of mercury in waters is significant at approximately 30%. The concentration of Hg^{2+} was 50% and the remaining 20% were other species (Kudo, 1982). Modeling of mercury dynamics indicated that mercury in well water is highly unlikely to be methylated to the toxic methylmercury form (Stolzenburg et al., 1986).

Metallic mercury, with its uniquely high vapor pressure relative to other metals, can enter the atmosphere from the aquatic environment as several different gaseous compounds. This factor makes volatilization important for the aquatic fate of mercury. The rate of vaporization of mercury and certain of its inorganic compounds decreases in the sequence $\text{Hg} > \text{Hg}_2\text{Cl}_2 > \text{HgCl}_2 > \text{HgS} > \text{HgO}$ according to the data of Koksay and Bradshaw (1969).

Presumably, the microbial methylation of mercury would enhance the evaporative loss of mercury. Although monomethyl mercury compounds are the principal product of biological methylation rather than the non-ionizable dimethyl mercury (Jensen and Jernelov 1969), a net increase in volatility should result. Because of limited quantitative data available on the subject of the volatilization of mercury compounds from natural waters, it is not clear what impact volatilization will have on the overall fate of mercury in the aquatic environment.

Mercury shows a tenacious affinity for surfaces of many types. The problems of storing dilute aquatic mercury samples in glass vessels have been well known for years. In natural samples, a major portion of the total mercury has been found associated with the particulates (Hinkle and Learned, 1969). Studies on the addition of mercury to a variety of natural samples have lead to the same conclusion. Carr and Wilkniss (1972) found that radioactive mercury, when added to stored samples, was rapidly apportioned onto the particulate phases with half-lives for adsorption of less than one to 50 hours. This experiment

indicated that the adsorbed species are probably not methylated mercury compounds. The work of Kudo et al. (1977) supports this contention by demonstrating that there is no significant isotopic exchange between $^{203}\text{HgCl}_2$ and CH_3HgCl or $\text{CH}_3^{203}\text{HgCl}$ and HgCl_2 .

Reimers and Krenkel (1974), in their study of mercury adsorption and desorption on sediments, reported that at a constant pH, the adsorption of inorganic mercury is affected by aquatic chloride concentration, with the percent loss in capacity depending upon the constituents of the sediment. The sedimentary material studied exhibited a capacity to sorb methylmercury that followed the order:

organics >> illite >> montmorillonite >> sand

They found, as well, that inorganic mercury is bound strongly enough by sediments to be transported by sedimentary mobilization.

Inoue and Munemori (1979) examined the coprecipitation of mercury (II) with iron (III) hydroxide. Mercury is coprecipitated over the whole pH range of 4 to 12. The Hg(II) species that coprecipitated was inferred to be Hg(OH)_2 based on chemical equilibrium considerations.

Adsorption of both Aretan (2-methoxymethyl mercury) and HgCl_2 correlated well with the distribution of organic carbon and with the cation exchange capacity (CEC) of soils (Semu et al., 1986). The lack of such correlation in the other soils studied suggests other reactions like precipitation may also be involved in mercury retention by soils in addition to purely adsorptive process. The affinity of mercury for the sulfhydryl group can bind it to suspended organic matter, both living (e.g., plankton) and nonliving (e.g., peat and humus). In aquatic environments, as organic and inorganic suspended matter settles, mercury is delivered to the sediment.

In summary, it is evident from environmental studies and theoretical considerations, that mercury adsorption onto the sediments is probably the most important process for determining the fate of mercury in the aquatic environment.

5.3.2 Mercury at the Vineland Chemical Company Site

The most probable sources of mercury in the soils of the site are mercury based pesticides spilled or dumped there. If these organic forms are oxidized within the soil and groundwater, the absorption on sand and coprecipitation with iron would probably bind most of it to the soils. The lack of measurable mercury in the waters of the site suggests a very high K_d , consistent with the high adsorption concept. Mercury does not appear to have much mobility since it is concentrated on surface soils. Most likely then, mercury has a relatively low mobility on this site at least when compared with arsenic and cadmium. The oxidatio

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states indicated by iron and pH suggest that mercury solubility potentially has a broad range based in Figure 5-8. The lack of mercury in the groundwaters would suggest that the soil-bound mercury is in some highly insoluble or surface reactive organic or inorganic form and is not governed by the equilibria described in Figure 5-8. Figure 5-8 shows mercury equilibria and solubility in the presence of low chloride and sulfur levels. Although these chloride and sulfur levels are above those expected at the site based on U.S.G.S. measurements at Norma, New Jersey, they are sufficiently close so that the figure can still be used to demonstrate the difference between site conditions and those of mercury equilibria.

The potential impact of mercury on the waters leaving the site and entering a stream appears very small since no dissolved mercury was found. Thus all water on the site would meet the New Jersey and federal clean water standards for mercury. It is possible, however, that during the site remediation, certain cleanup techniques such as groundwater "pump and treat" will raise the groundwater Eh and greatly increase the mercury mobility.

The range of mercury found on the soils of the site (0-11 mg/kg) does indicate significant anthropogenic contamination when compared with background levels for mercury on sandy soils of 0.01 to 0.54 mg/kg.

5.4 LEAD

5.4.1 Geochemistry of Lead

Lead exists in three oxidation states, 0, +2, and +4. Although neither metallic lead nor the common lead minerals are classified as soluble in water, they can be solubilized by some acids; in contrast, some of the lead compounds produced industrially are quite water soluble. Therefore, natural compounds of lead are not usually mobile in normal groundwater or surface water because the lead leachate from ores becomes adsorbed by ferric hydroxide or tends to combine with carbonate or sulfate ions to form insoluble compounds (Hem, 1976).

The average abundance of lead in the earth's crust is approximately 15 mg/kg (Lovering, 1976) which is equivalent to one-half ounce of lead per ton of rock. Shales and unconsolidated sediments have a mean lead abundance close to the crustal average, showing the fairly even distribution of lead in the environment. The range of concentrations of lead in sandy soils in the US is <10 to 70 mg/kg.

Lead in soil may be derived from natural or anthropogenic sources. The natural sources include weathering of rocks and ore deposits, volcanoes (mantle degassing), fires, and wind-blown dust. The anthropogenic contribution of lead in soils is a relatively recent event (100 years or so), but it has increased to such an extent that the build-up of lead concentrations in many soils has significant biological effects.

Lead exists in aqueous solution almost entirely as Pb (II) species. The equilibrium reaction $\text{Pb}^{4+} + 2\text{e}^- \rightleftharpoons \text{Pb}^{2+}$, has a pe value of over +21, and thus Pb(IV) species exist only under extremely oxidizing conditions (Cotton and Wilkerson, 1972). Pb(II) forms a number of hydroxide complexes. These include $\text{Pb}(\text{OH})$, $\text{Pb}(\text{OH})_2$, and $\text{Pb}(\text{OH})_3$. Lead is predominantly $\text{Pb}(\text{OH})^+$ at pH 6.3 and lead activities less than 0.001 M $\text{Pb}(\text{OH})_3$ dominates above pH 10.9 and polynuclear species dominate when total Pb > 0.001 M (EPA, 1986).

An outstanding characteristic of lead is its tendency to form complexes of low solubility with the major anions of natural environmental systems. The hydroxide, carbonate, sulfide, and (more rarely) the sulfate of lead may act as solubility controls. If sulfur activity is very low, metallic lead can be a stable phase in alkaline or circumneutral reducing conditions.

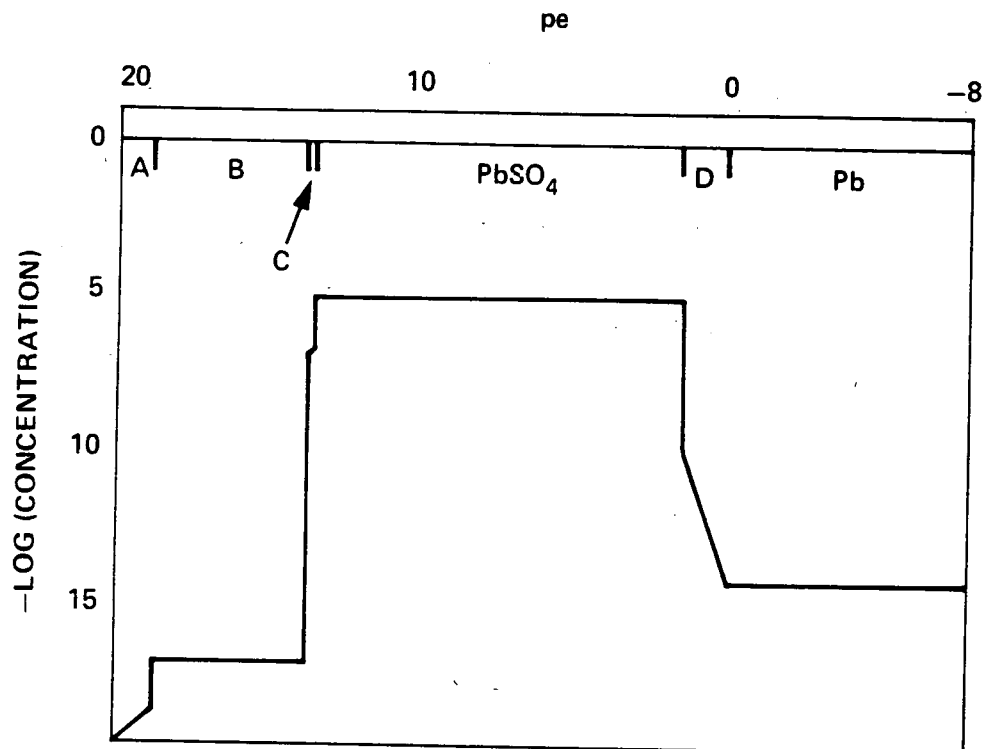
Huang *et al.* (1977) calculated the equilibrium solubility of lead as a function of pe for a system with total carbonate and total sulfur concentrations of 10^{-3} M at pH 7. Figure 5-9 shows the solubility of lead and the controlling solid species for the pe range encountered in natural waters.

Dissolved lead may be hydrolyzed to form $\text{Pb}(\text{OH})_2$. Patterson *et al.* (1977) studied the formation of $\text{Pb}(\text{OH})_2$ versus PbCO_3 to determine the feasibility of treating lead-containing waters with carbonates. They found that PbCO_3 controls lead solubility at pH 11.5. Even small concentrations of inorganic carbonate due to dissolution of atmospheric CO_2 are sufficient to reduce the solubility of lead to concentrations below those predicted on the basis of hydrolysis alone. It should be noted that lead concentrations were reduced nearly to the computed solubility limits within four hours; thus, precipitation of lead carbonate can occur quickly.

Lead forms organic complexes with various ligands: amino acids, proteins, polysaccharides and fulvic and humic acids. At the low concentration in which lead is normally found in the aquatic environment, almost all of the lead in the dissolved phase may be complexed by the ligands of river water. By using an ion-specific electrode, Ramamoorthy and Kushner (1975) determined that lead binding capacity was predominantly due to organic compounds. Inorganic complexes were not important, since evaporating the water samples, ashing the residue, and reconstituting the ash in water resulted in complete loss of the binding capacity. (In waters with a high carbonate concentration, however, binding by HCO_3^- or CO_3^{2-} is important).

Jackson and Skippen (1978) investigated the behavior of lead and organic materials at a simulated sediment-water boundary. The interactions involved sorption by clays, organic complexing, carbonate reactions, hydrolysis, and desorption of lead from clay and metal hydroxides. They found that organic acids decreased the solubility of lead in the presence of clay, particularly at acidic pH values. This organic complexing

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KEY:

- A = PbO_2
- B = $\text{Pb}_3(\text{OH})_2(\text{CO}_3)_2$
- C = PbCO_3
- D = PbS

MODIFIED FROM HUANG ET AL. (1977).

U.S. ENVIRONMENTAL PROTECTION
AGENCY

VINELAND CHEMICAL COMPANY SITE

FIGURE 5-9

SOLUBILITY OF LEAD
AS A FUNCTION OF pe

EBASCO SERVICES INCORPORATE

VIN 001 1142

probably due to colloidal coagulation. The organic acids, moreover, proved capable of remobilizing lead from the solid phase. There is, however, a general kinetic hindrance to this desorption, particularly at basic pH values.

Tetra-alkyl lead compounds apparently can be formed in natural aquatic sediments. They can have serious implications for man-made pollution of waterways because tetraalkyl lead is considerably more toxic than inorganic lead. Craig and Rapsomanikis (1985) demonstrated the production of methyl lead derivatives from the reaction of Pb(II) ions with CH₃ donor agents. They also suggested some reaction mechanisms. Two static bioassays (on rainbow trout) in hard water resulted in a 96 hr LC₅₀ (lethal concentration with 50% survival) of 1.32 and 1.47 mg/l dissolved lead with a total lead LC₅₀ of 542 and 471 mg/l, respectively (Davis *et al.*, 1976). The experiment demonstrated that the dissolved fraction is directly toxic to fish in aquatic environments.

Sorption processes appear to exert a dominant effect on the distribution of lead in the environment. Several investigators have reported that, in aquatic and estuarine systems, lead is removed to the bed sediments in close proximity to its source, apparently due to sorption onto the sediments (Helz *et al.* 1975; Valiela *et al.* 1974). Different sorption mechanisms have been invoked by different investigators; the relative importance of these mechanisms varies widely with such parameters as geological setting, pH, E_h, availability of ligands, dissolved and particulate iron concentration, salinity, composition of suspended and bed sediments, and initial lead concentration.

The adsorption of lead to soils and oxides was studied by Huang *et al.* (1977). The data indicate that adsorption is highly pH-dependent, but above pH 7, essentially all of the lead is in the solid phase. It should be noted that at low pH, lead is repelled from the adsorbent surface. The addition of organic complexing agents increased the affinity for adsorption. Therefore, the tendency for lead to be adsorbed probably reflects the fact that lead is strongly complexed by organic materials in the aquatic environment (Ramamoorthy and Kushner, 1975). Huang *et al.* (1977) speculate that the increased adsorption is due to the ability of the metal-ligand complexes to share free electrons, thus facilitating sorption to electrophilic solid surfaces.

Several authors, notably Jenne (1968), Lee (1975), and Hohl and Stumm (1976), have hypothesized that the sorption of heavy metals by hydrous iron and manganese oxides is a major control on the mobility of these pollutants in the aquatic environment. On the basis of a high correlation between the lead, iron and manganese concentration in sediments, Angino et al. (1974) suggested that sorption by iron and manganese oxides is the dominant sorption process in several Kansas streams. Gaddie and Laitmen (1973) demonstrated that hydrous iron oxides have a high sorption capacity for lead, sorbing as much as 0.28 moles lead per mole iron at pH 6. The ability of hydrous iron oxides to sorb lead increases with increasing pH. At pH 8.1, 91% of the added lead was sorbed. When the pH drops, however, lead may be desorbed. Although the relative importance of individual sorption processes varies widely, it appears that, in most circumstances, lead is effectively removed to the sediments by sorption.

In summation, the transport of lead in the aquatic environment is dominated by the sediment bound phase, which in turn is influenced by the speciation of the ion. Although lead will exist mainly as the divalent cation in most unpolluted waters and become sorbed into particulate phases, organic material in polluted waters will have a great effect on the chemical form in which lead will be present.

5.4.2 Lead at the Vineland Chemical Company Site

The levels of lead found in the soil material (from non-detect to 23 mg/kg) are within the range of lead in sandy U.S. soils (10 to 70 mg/kg) as shown in Table 4-3. There are, however, a significant number of values above the background lead level determined from Ebasco wells 1, 9 and 12 of about 2 mg/kg, indicating some small scale contamination. The aqueous levels of lead are fairly low with a range from the non-detect limit to 110 ug/l in the groundwater. No lead was found in the lagoon water, suggesting that lead is no longer being released at the site. The presence and similar range of aqueous lead in all of the groundwaters at the site would suggest that most of the detected levels are naturally occurring with an occasional local contamination. At these lower levels and frequency of occurrence, sample contamination may also be a factor.

The range of soil and water lead levels give Kds of 100 to 600, indicating a low mobility for lead relative to cadmium and arsenic. This high Kd is consistent with the measured high absorption rates for lead in the literature. The level of aqueous lead in the groundwater is mostly less than the New Jersey and federal clean water requirements of 50 ug/l with only six samples above this limit.

The presence of iron oxides on the site soils probably provides a significant number of sites for lead absorption. The lack of organic materials in the aquifer soils would suggest that the lead is in an inorganic form, although it is highly possible that the releases from the plant or the surface soils at the site could supply a sufficient number of ligands to tie-up lead as organic dissolved and particulate forms.

5.5 TRICHLOROETHYLENE

5.5.1 Geochemistry of Trichloroethylene

Trichloroethylene (TCE) is a colorless, highly volatile liquid that has been used mainly as an industrial solvent in the liquid or vapor form for degreasing of metal parts before finishing (Clayton, 1981). It is also used as a dry cleaning solvent, an extractive solvent in food production, and a chemical intermediate or solvent in the production of pesticides, waxes, gums, resins and tars (USEPA, 1975). It has found some limited application as an inhalation anesthetic and analgesic during certain short-term surgical procedures but is no longer used for these purposes in the United States (Huff, 1971).

TCE does not occur naturally in the environment. Volatilization of TCE during production and use is the major source of this compound in the environment. TCE is one of the most commonly found contaminants in groundwater (Dyksen *et al.*, 1982). In addition, it has been detected in air, food, and human tissues (Pearson and McConnell, 1975).

TCE is not expected to persist in the environment. The processes that affect the transport and removal of trichloroethylene include volatilization, adsorption/desorption, and degradation.

Volatilization

Trichloroethylene, as evidenced by its Henry's Law Constant (9.1×10^{-3} atm-m³/mol), is volatile (see Table 5-10). In surface waters, volatilization is considered the most significant fate of TCE (Versar, 1979). Volatilization rates are dependent upon temperature, water movement and depth, associated air movement, and other factors. The volatilization half-life of TCE from a rapidly moving, shallow river (1 m deep, flowing at 1 m/s with a wind velocity of 3 m/s) has been estimated to be 3.4 hours (Lyman *et al.* 1982). Estimated volatilization half-lives from representative environmental bodies are: pond, 11 days; lake, 4 to 12 days; and river, 1 to 12 days (EPA, 1985).

Little data are available on the volatilization rate of trichloroethylene from soil. In soil column studies, loss of TCE due to volatilization was calculated to range from 15.6 to 32.8% (Walker, 1984).

TABLE 5-10

PHYSICAL CHARACTERISTICS OF CHEMICAL CONTAMINANTS

CHEMICAL	VAPOR PRESSURE MM Hg @ 20°C	WATER SOLUBILITY mg/l @ 20°C	OCTANOL/WATER PARTITION COEFFICIENT (log ₁₀)	SOIL/SEDIMENT ADSORPTION COEFFICIENT (log ₁₀)	SPECIFIC GRAVITY (20°C)	MOBILITY INDEX
<u>Volatile Compounds</u>						
Acetone	270	1 x 10 ⁶	-0.24	2.2	0.791	
Benzene	76	1780	2.13	1.99	0.879	3.2 Very Mobile
Carbon disulfide	3.6 x 10 ²	2.94 x 10 ³	2.0		1.263	
Chloroform	160	8000	1.97	1.59	1.489	4.5 Very Mobile
Methylene chloride	349	20000	1.25	1.16	1.326	5.6 Extremely Mobile
Toluene	22	515	2.69	2.51	0.867	1.5 Very Mobile
1,1,1-Trichloroethane	100	4400	2.17	1.75	1.35	4.0 Very Mobile
Trichloroethene	60	1.1	2.29	3.76	1.46	2.7 Very Mobile
Trans-1,3 dichloropropene	2.5	2.80 x 10 ³	2.00			
<u>Base/Neutral Compounds</u>						
Benzo(b)fluoranthene	10 ⁻¹¹ -10 ⁻⁶	0.009	6.57	6.15	N/A	-14 Immobile
Bis(2-ethylhexyl)phthalate	2 x 10 ⁻⁷	0.4	8.73	8.17	0.99	-13 Immobile
Butylbenzylphthalate	8.6 x 10 ⁻⁶	2.9	5.8	5.43	1.1	-8 Immobile
Di-n-butylphthalate	0.1	13	5.2	4.87	1.0465	-4 Slightly Mobile
Di-n-octylphthalate	0.2	3	9.2	8.61	0.99	-6.8 Immobile
<u>Pesticide Compounds</u>						
Beta-BHC	N/A	N/A	N/A	N/A	N/A	N/A
4,4-DDT	1.5 x 10 ⁻⁷	0.006	6.19	4.86	N/A	-14 Immobile
Dieldrin	3.1 x 10 ⁻⁶	0.2	5.6	4.02	1.75	-10.2 Immobile
Endosulfan	1 x 10 ⁻⁵	0.5	3.6	3.81	N/A	-9 Immobile
Endrin ketone						
Gamma BHC	1.6 x 10 ⁻⁴	7.8	3.9			
Heptachlor	3 x 10 ⁻⁴	1.8 x 10 ⁻¹	4.40			
<u>PCB</u>						
Aroclor 1254	7.7 x 10 ⁻⁵	0.056	4.11	3.85	1.35	-8.4 Immobile

Adsorption/Desorption

Trichloroethylene has been shown to adsorb to various soil components, including clay, humic acid, lignin and other organic matter (Garbarini, 1986).

The relationship between the amount of trichloroethylene sorbed to solid phase soils and the aqueous phase trichloroethylene concentration is often expressed as the Freundlich isotherm

$$X/M = KC^{1/n}$$

Where X = mass of trichloroethylene sorbed (mg)

M = mass of sorbent (kg)

C = equilibrium trichloroethylene concentration in the aqueous phase (mg/l)

K = a partition or distribution coefficient

1/n = a constant indicative of adsorptive capacity.

When 1/n = 1, the equation describes a partitioning or distribution between the two phases by a linear relationship.

The equation for the linear isotherm is

$$X/M = KC$$

This linear isotherm equation has found wide use in many soil adsorption studies, particularly at low solute concentrations.

Related to the linear partition coefficient is a coefficient K_{OC} , which is based upon the absorption by organic carbon. K is then a function of the fraction of organic carbon in the soil.

The relationship is: $K = K_{OC} f_{OC}$

Where f_{OC} = fraction of organic carbon in adsorbent.

Factors which have been demonstrated to influence the magnitude of K include:

1. Octanol: water partition coefficient (K_{OW}). K_{OC} can be estimated from K_{OW} by the following equation:

$$K_{OC} = 0.63 K_{OW} \text{ (Karickhoff, 1981)}$$

2. Particle size of soil. Since adsorption is a surface phenomenon, the extent of adsorption should be directly related to the surface area of the adsorbent (soil), which in turn is related to particle size. (Karickhoff, 1979; Schwayenbach, 1981).
3. Organic carbon content of soil. Experimentally measured trichloroethylene partition coefficient values have been reported to range from 58.1 to 155.8 l/kg for soils of differing chemical composition (Walker, 1984, Seip *et al.*, 1986; Garbarini and Lion, 1986), indicating high soil mobility. Significant movement of trichloroethylene in soil was also demonstrated in a field study when trichloroethylene was observed to infiltrate rapidly from river water into groundwater (Schwayenbach, 1983).

Degradation

Chemical degradation

The primary transformation process for trichloroethylene in the atmosphere is reaction with sunlight-produced hydroxyl radicals (Singh *et al.*, 1982). The half-life of trichloroethylene was estimated to be 6.8 days, and the degradation products of this reaction was reported to include phosgene, dichloroacetyl chloride, and formyl chloride (Atkinson, 1985). On the other hand, trichloroethylene in water can resist hydrolysis at 100°C (Drilling *et al.*, 1975). USEPA reports that under normal conditions, TCE is not hydrolyzed in water (USEPA, 1979). In addition, oxidation and photolysis are not environmentally important processes for trichloroethylene in water (Callahan *et al.*, 1979).

Biodegradation

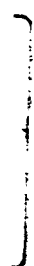
Biodegradation of trichloroethylene occurs under anaerobic condition in soil. The primary product is 1,2 - dichloroethylene (with cis isomer preferred over trans isomer), and with small amounts of vinyl chloride production (Kleopfer, 1985).

5.5.2 Trichloroethylene at the Vineland Site

The very low level of fines and the low organic carbon content in the soils of the site would suggest a low value for the partitioning coefficient (K_d) for TCE. The lack of any measurable TCE on the soils along with the very low dissolved levels in the groundwater also suggest a very low K_d . Thus, TCE can be expected to move fairly rapidly from the groundwater under the site to the nearby streams. The lack of any TCE in the surface soils or lagoon waters and its concentration in the mid-depth aquifer would suggest that TCE is not being released at the site at present. Given the short-term variation seen in

the TCE concentrations in some of the wells, the most probable cause of the TCE is localized dumping and spills which occurred on the site. The low concentrations of TCE would indicate that these releases were either relatively small or that most of the TCE evaporated through the soil. The possibility that the TCE has an off-site origin cannot be completely ruled out. The chemical degradation of TCE is probably not important on this site given the short residence time of groundwater under the site. The lack of anaerobic breakdown products would suggest that this process is not important either, although there was no analysis for cis-1,2 dichloroethene, the main product of this process.

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6.0 BASELINE RISK ASSESSMENT

The public health evaluation of the ViChem plant site area had two objectives. The first was to assess the nature and extent of potential public health risks associated with the plant in its present condition. This allows a decision as to whether or not the plant requires remedial action. The second was to help determine cleanup levels if it is decided the area requires remediation.

A public health evaluation involves four steps. The first step is to identify indicator chemicals to address potential public health and environmental concerns. A toxicity evaluation and a dose-response assessment provide qualitative and quantitative evidence to determine whether the contaminants detected at the site may be associated with adverse health and/or environmental effects. The second step identifies critical exposure pathways and defines receptors at risk via each potential exposure pathway. In this evaluation receptors are considered to be individuals that may be exposed to toxic chemicals. The third step determines the plausible site-specific scenarios that cause exposure of contaminants to the identified receptors and the most likely concentrations associated with these scenarios. The values are then used to calculate the critical exposure pathways for more "typical" site conditions. The final step in the process is the calculation of the risks.

6.1 SELECTION AND TOXICOLOGICAL EVALUATION OF INDICATOR CHEMICALS

6.1.1 Selection of Indicator Chemicals

Over 40 chemicals were detected in and around the ViChem plant site. To simplify the risk assessment process, the results of the investigations were reviewed and the chemicals most likely to contribute to potential human risks were selected for detailed examination. The selection of these indicator chemicals was based on their concentrations and frequencies of occurrence, and upon their toxicological, physical, chemical, and environmental fate characteristics. As part of the selection process, the concentrations of the potential inorganic pollutants detected were compared to naturally occurring background levels to determine which were present in abnormally high concentrations. Background levels for several inorganics in New Jersey and US soils are shown in Table 4-3. All chemicals present in high concentrations were noted. However, particular attention was given to those chemicals that were known to be used, manufactured or stored at the ViChem plant. A list of the chemicals linked with production activities is shown in Table 1-2.

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Groundwater

Groundwater was sampled in two rounds (July and September, 1987) from 11 existing ViChem monitoring wells and 36 monitoring wells installed by Ebasco. As described in Sections 2.5 and 2.6, the shallow wells were located in the upper portion of the upper sand, medium wells were located at the base of the upper sand, and deep wells were located at the base of the middle sand. Groundwater samples were also taken from an on-site production well. This well extends into the Upper Kirkwood aquifer to a depth of 130 feet. It is located upgradient of the production area and is used to supply process and cooling water for the still-active facility. Several organic and inorganic compounds were detected in groundwater samples from every depth. Results of the sampling are shown in Table 4-5 and are discussed below.

Organic Compounds. Acetone, methylene chloride, trans-1,3-dichloropropene, bromoform, carbon disulfide, 1,1-dichloroethane, carbon tetrachloride, benzene, and tetrachloroethane were detected infrequently at low levels in several groundwater samples. Diethylphthalate, bis(2-ethylhexyl)phthalate, di-n-octyl phthalate, diethylphthalate and indeno-[1,2,3-cd]pyrene were each detected once or twice; however, all concentrations were below 4.0 ug/l, with the exception of indeno-[1,2,3-cd]pyrene, which was detected at 20 ug/l. Chloroform and 1,1,1-trichloroethane were detected more frequently (8/95 and 16/101 samples, respectively); however, their concentrations were also low (1.0 ug/l to 6.7 ug/l) and all but one detection were flagged as estimated. Due to the infrequency of detection and because there is no reason to assume that these low-level detections are associated with the activities of the ViChem facility, none of these compounds were selected as indicator chemicals.

Low concentrations of pesticides and PCBs were detected infrequently in wells at every depth. The distribution of the pesticides and PCBs showed no distinct pattern of contamination that would suggest that these chemicals were originating from the ViChem plant (Figure 4-13). The only PCB detected was Arochlor 1254 (2 and 17 ug/l) at the medium depth wells EW-6 and EW-1. Because none of the compounds detected were thought to be site-related contaminants, none were selected as indicator chemicals.

Trichloroethene was detected in 22 out of 101 samples in concentrations ranging from 1.0 to 1600 ug/l. The highest levels of contamination were found in medium depth wells in the vicinity of chicken coop #3 (MW-6 and EW-14; Figure 4-12). Trichloroethene has been associated with activities at

the ViChem plant and was selected as an indicator compound in groundwater.

Inorganic Compounds. Most inorganic compounds on the Hazardous Substances List (HSL) were detected in groundwater samples (Table 4-5). Arsenic was detected at concentrations from 2.1 to 394,000 ug/l and was found at all depths. However, the highest concentrations and greatest frequency of occurrences were found in intermediate and shallow wells in the areas around the production/lagoon area and in the southwest corner of the study area near chicken coop #3 (Figures 4-7, 4-8 and 4-9). Cadmium was detected in 43 out of 100 samples in concentrations ranging from 4.9 to 9580 ug/l. In a pattern similar to arsenic, the highest concentrations of cadmium were found in intermediate groundwater below and downgradient of the lagoon area and in the "hot spot" near chicken coop #3 (Figures 4-10, 4-11). The history of arsenical herbicide, fungicide, and biocide manufacturing and cadmium usage by ViChem, coupled with the presence of a plume of arsenic/cadmium contamination originating from the ViChem production/lagoon area and extending northwest (the direction of groundwater flow), strongly suggest that ViChem is the source of the high concentrations of arsenic and cadmium found in the area. Arsenic and cadmium were selected as indicator compounds in groundwater.

Lead was detected in 40% (27/68) of the total wells tested. Concentrations ranged from just above detection limits to levels exceeding primary industry drinking water standards (3.0 to 110 ug/l). Because detection was frequent and levels exceeded the MCL and MCLG, lead was selected as an indicator compound.

Although mercury, aluminum and iron have been used, manufactured or stored at the ViChem plant, these compounds were detected infrequently or at concentrations consistent with expected background values and, therefore, were not chosen as indicator chemicals. The remainder of inorganic compounds also fell within normal background levels.

Summary. In summary, trichloroethene, arsenic, cadmium, and lead were chosen as indicator chemicals for groundwater. Descriptive statistics are given in Table 4-6 and the distribution of concentrations is shown in Figure 4-6.

Surface water (lagoon water)

Surface water samples were taken from both lined and unlined lagoons (Figure 4-15) during both rounds of groundwater sampling. High concentrations of arsenic were detected in the lined lagoons (698-3600 ug/l), and arsenic was therefore selected an indicator chemical for lagoon water. A lower concentration of arsenic (11 ug/l) was found in the unlined lagoon, where wastewater entering these lagoons is mixed with noncontaminated

cooling water obtained from the on-site production well. Aluminum, chromium, iron, manganese, mercury, nickel and other inorganics were also detected in lagoon samples, but were not considered to be at unusually high concentrations (Table 4-8). The base-neutral compound bis-2-ethylhexylphthalate was detected only in the second round of sampling (16, 20, and 26 ug/l), but may be present as a result of lab and/or field contamination and was not considered to be a contaminant of concern.

River Water Samples

Surface water from the Blackwater Branch of the Maurice River was sampled for organic and inorganic contamination. No organic compounds other than a few lab contaminants (Table 4-10) were detected in river samples and all inorganic compounds with the exception of arsenic were considered to be within normal background ranges. Arsenic was detected above the background levels in all samples (6/6) in concentrations ranging from 4.8 to 6200 ug/l (Figure 4-14). Arsenic was therefore selected as an indicator compound.

Soils

Surface soils samples were taken throughout the ViChem plant property at 98 sample sites (Figure 4-1) and from near the unlined lagoons (Figure 4-15). Samples were taken from nearby off-site areas (Figure 4-5) to address the possibility of contaminated soil being blown off-site by the wind. Chicken coops that were suspected of being contaminated at the beginning of the study were sampled for arsenic-containing dust. To examine subsurface soils, Ebasco drilled 29 soil borings (Figure 4-3 and 4-4). Additional subsurface soil samples were obtained during the construction of the 36 Ebasco monitoring wells. Subsurface soil samples were also taken from five designated boring locations in building #9. Table 4-1 shows a summary of the chemicals that were detected in the surface and subsurface soils in and around the ViChem facility.

Organic Chemicals. Diethylphthalate and butylbenzylphthalate were detected at low concentrations in several soil samples but were not chosen as indicator chemicals because they are common laboratory contaminants and are not likely to be associated with the manufacturing operations. Dieldrin, 4-4-DDT, and bis-2-ethylhexylphthalate are relatively commonly occurring environmental contaminants and are not specific to this site. As these chemicals were only found infrequently and at low concentrations, these chemicals were not selected for further consideration. Although methylene chloride is a common laboratory contaminant, it was detected at high concentrations in several subsurface soils. Methylene chloride was detected in 15/42 trip and field blanks at concentrations ranging from 3 to 1000 ug/l.

Owing to frequent lab and/or field contamination and almost 40% of the samples (26/68) being rejected for methylene chloride,

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methylene chloride was not selected as an indicator chemical for subsurface soils. No other organic chemicals were detected with sufficient frequency to justify their selection as indicator chemicals. Therefore, no organics were chosen as indicator chemicals.

Inorganic Chemicals. Barium, calcium, potassium, sodium, nickel, magnesium, lead and zinc were detected in several samples. However, levels were considered to be within the range of normal variability for naturally occurring elements. Because these compounds are not associated with the processes at this site, they were not chosen as indicator chemicals. Arsenic, aluminum, iron, and mercury are chemicals that are known to be associated with the operations at the ViChem facility. Arsenic, iron and mercury were detected frequently in surface soils. Given that the local soils are naturally high in iron, the concentrations of iron detected did not appear to be above background levels. Mercury did not appear to be present in subsurface soils at concentrations exceeding the normal range of variability for naturally occurring elements. However, it was detected at high concentrations in surface soil samples. Off-site soils were analyzed for arsenic only and 12 out of 17 samples showed arsenic ranging from 0.9-78 mg/kg. (The highest level detected, 78 mg/kg, was sampled close to the soil dumping area by EW-15. This area was resampled, further removed from the dumping area, and arsenic was undetected at a detection limit of 2 mg/kg). Therefore, arsenic was chosen as an indicator chemical for subsurface and off-site soils and both arsenic and mercury were selected as indicator chemicals for surface soils. Descriptive statistics for arsenic and mercury detected in surface soils are given in Table 4-2 and statistics for arsenic in off-site soil samples are given in Table 4-4. Histograms of concentration distributions are given in Figure 4-2 for surface soils and Figure 4-4 for off-site soils.

River Sediments

Sediment samples were analyzed for arsenic and iron at three locations along the Blackwater Branch (Figure 4-16). Arsenic was detected in all samples at levels ranging from 61-6200 mg/kg and therefore selected as an indicator compound. Although iron concentrations were high (1470-47800 mg/kg), high iron concentrations are common in this area of New Jersey and the toxicity of iron is low. Therefore, it was not selected as an indicator compound.

Lagoon Sediments

Sediments from unlined lagoons were analyzed only for arsenic and iron. Arsenic was detected in all lagoon sediment samples in concentrations ranging from 25-185 mg/kg. Iron was found in all sediment samples in concentrations ranging from 731-3002 mg/kg, which were not considered to be above the normal background level for this area. Therefore, only arsenic was selected as an indicator chemical.

Chicken coops

Chicken coops were sampled for inorganic compounds only. High levels of arsenic, cadmium, lead, mercury, and zinc were detected in dust samples taken from the coops (Table 4-7). Hence these compounds were retained as indicator chemicals.

Summary. Arsenic was chosen as an indicator for off-site soils, subsurface soils, river sediments, and lagoon sediments. Arsenic, cadmium, lead, mercury and zinc were selected as indicator compounds for the chicken coop. Arsenic and mercury were chosen as indicator chemicals for surface soils.

Overall, the following chemicals were selected as indicator chemicals at the ViChem site:

Groundwater

- o Arsenic
- o Cadmium
- o Lead
- o Trichloroethene

Lagoon Water

- o Arsenic

River Water

- o Arsenic

Surface Soil

- o Arsenic
- o Mercury

Off-Site Soil

- o Arsenic

Chicken Coops

- o Arsenic
- o Cadmium
- o Lead
- o Mercury
- o Zinc

Subsurface Soil

- o Arsenic

Lagoon Sediments

- o Arsenic

6.1.2 Toxicological Evaluation

This section provides a review of the scientific data regarding the health and environmental hazards associated with exposure to the indicator compounds, and presents the toxicity criteria that will be used to determine whether the site-associated contaminants pose current or potential future hazards to human health and the environment. The Superfund Public Health Evaluation Manual (USEPA, 1986b) recommends that potential risks to human health be assessed by comparing the concentrations of the indicator chemicals present in and around the site with criteria that have been recommended for the protection of human health and the environment. The criteria suggested by the EPA for this purpose are referred to as applicable or relevant and appropriate requirements (ARARs) and include drinking water maximum

contaminant levels (MCLs) and maximum contaminant level goals (MCLGs), Federal Ambient Water Quality Criteria, National Ambient Air Quality Standards (NAAQS), and State Environmental Standards. Federal and State ARARs available for chemicals present at the ViChem site are shown in Table 6-1. A discussion of the assumptions and limitations associated with these parameters follows.

- o Maximum Contaminant Levels (MCLs) and the Maximum Contaminant Level Goals (MCLGs) - National Primary Drinking Water Standards MCLs, promulgated under the Safe Drinking Water Act, are enforceable standards for contaminants in public drinking water supply systems. MCLs are defined assuming lifetime exposure to a contaminant for a 70-kg adult who consumes two liters of water per day. MCLs are calculated to reflect exposure to a contaminant from all sources (e.g., air, food, water). They consider not only health factors, but also the economic and technical feasibility of removing a contaminant from a water supply system. Secondary Drinking Water Standards, which include MCLs for iron and manganese, are nonenforceable standards that consider the aesthetic quality of drinking water. The EPA has also proposed MCLGs for several organic and inorganic compounds in drinking water. MCLGs are guidelines and are based on health considerations only. It is important to note for reference that the MCL for arsenic, which is not solely health-based, is 50 ug/l, a level which corresponds to a cancer risk for adults (drinking two liters per day for 70 years) of 2.57×10^{-3} (based on a CPF for arsenic of 1.8 (mg/kg/day)-1).
- o Health Advisories - Health Advisories are nonenforceable guidelines, developed by the Office of Drinking Water, for chemicals that may be intermittently encountered in public water supply systems. Short-term Health Advisories are calculated for a 10-kg child (1-year-old infant) who ingests one liter of water per day for 1-day and 10-day exposure periods. Lifetime Health Advisories are calculated for a 70 kg adult assumed to drink two liters of water per day. Longer-term Health Advisories (one to two years) are calculated for both a 10-kg child and a 70-kg adult. These guidelines do not consider carcinogenic risks or synergistic effects. Health advisories are used to evaluate the potential for acute and chronic health effects associated with ingesting contaminated drinking water.
- o Ambient Water Quality Criteria (AWQC) - These are nonenforceable guidelines for the protection of human health from exposure to contaminants in ambient water. These criteria are estimates of the concentration the

TABLE 6-1

POTENTIAL CHEMICAL-SPECIFIC ARARs FOR INDICATOR CHEMICALS AT THE VICHEM SITE

Chemical	Safe Drinking Water Act MCLs/MCLGS ¹ (mg/l)	Clean Water Act Water Quality Criteria for Human Health Fish and Drinking Water	Clean Water Act Water Quality Criteria for Human Health Adjusted For Drinking Water Only	Safe Drinking Water Act Health Advisories (mg/l)			New Jersey POES ² Maximum Concentration of Constituents For Drinking Water In Milligrams Per Liter Unless Otherwise Specified	New Jersey Department of Environmental Protection Interim Action Levels (ug/l) and Recommendations for Responses for Selected Organics in Drinking Water ^m / Group				
				1- Day	10 Day	Longer Term		Level I	Level II	Level III	Level IV	
Inorganics												
Arsenic	0.05/0.05	0(2.2 ng/l)	25 ng/l				0.05					
Cadmium	0.01/0.005	10 ug/l	10 ug/l				0.01					
Lead	0.05/0.02	50 ug/l	50 ug/l				0.05					
Mercury	0.002/0.003	144 ng/l	10 ug/l				0.002					
Organics												
Trichloro-ethene	0.005/0	0(2.7 ng/l)	0(2.8 ng/l)	2.0	0.2	0.075	1	A	0-3.1	3.1<30	30<309	>309

Summary of Responses for Interim Action Levels

- Level I - No recommended action, random spot check sampling.
- Level II - Confirm sampling results; periodic monitoring; recommend alternative water sources and/or appropriate treatment techniques.
- Level III - Confirm sampling results; monthly monitoring; develop within one year alternative water supplies and/or appropriate treatment techniques for public community water systems; recommend appropriate remedial action to public noncommunity water systems; and quarterly progress reports from both public community and public noncommunity water systems.
- Level IV - Confirm sampling results; immediate remedial action for both public community and public noncommunity water systems.

- 1 - Maximum Contaminant Levels and Maximum Contaminant Level Goals
- 2 - Public Discharge Elimination Systems

8511 100 NIA

will not result in adverse health effects in humans; and for known or suspected carcinogens, the concentrations associated with incremental lifetime cancer risks of 10^{-4} (one additional case of cancer in 10,000 people exposed) through 10^{-7} (one additional case of cancer in 10,000,000 people exposed). AWQC have been used by many states to develop enforceable ambient water quality standards. These criteria are used to evaluate the potential for noncarcinogenic and carcinogenic health risks associated with exposure to contaminants in drinking water.

- o New Jersey Pollution Discharge Elimination Systems (NJPDDES) Maximum Concentrations of Constituents for Drinking Water - These are the standards written into NJPDDES Permits.
- o New Jersey Department of Environmental Protection (NJDEP) Interim Action Levels and Recommendations for Responses for Selected Organics in Drinking Water - These action levels are guidelines developed by the State of New Jersey in the absence of State MCLs for contaminants in drinking water. The action levels are developed in consideration of human health effects and are derived using EPA Suggested-No-Adverse Response Levels (SNARLs), Recommended Maximum Contaminant Levels (RMCLs), or carcinogenic risks (1×10^{-6} lifetime cancer risks). The Levels (Levels I through IV) initiate various actions by NJDEP if the contaminants are identified in water supplies at the specified concentrations.

In instances where ARARs are not available for the chemicals at a site, or where the exposure to more than one contaminant occurs, a more complete quantitative or semiquantitative risk characterization must be performed. This involves using the concentrations of chemicals present at the site, along with various assumptions about the characteristics of the population exposed and the chemicals present, to predict the intake of contaminants by populations at risk. These predicted intake levels are compared with health-based criteria to determine whether the estimated intake poses a threat to human health. In order to develop the health-based criteria, extensive examinations of the toxicities of the compounds were undertaken. The following types of toxic effects were considered:

- o Noncarcinogenic effects - Toxic effects other than increased risk of cancer. Toxicological endpoints, routes of exposure, and doses in humans and/or animal studies are provided where appropriate.

- o Carcinogenic effects - Any chemical exposure which could potentially be associated with an increased probability of contracting cancer. Toxicological endpoints (types of tumors, organ system(s) affected), routes of exposure, and doses in humans and/or animal studies are provided where they are known.
- o Environmental effects - Acute and chronic toxic effects observed in aquatic biota and/or terrestrial wildlife.

From this toxicological examination, a determination of the relationship between the dose (amount of compound to which an individual or population is exposed) and the potential for adverse health effects was derived. These dose-response relationships provide a means by which potential public health impacts may be evaluated. Dose response relationships for different effects can be expressed using carcinogenic potency factors (CPFs), reference doses (RfDs) and acceptable chronic intakes (AICs). These criteria are discussed below. The CPFs and AICs or RfDs available for chemicals present at the ViChem site are shown in Table 6-2. Detailed toxicological information about indicator chemicals and the basis for criteria values can be found in the toxicological profiles provided in Appendix J.

- o Reference Dose - The potential for noncarcinogenic effects to occur as a result of exposure to site-related hazardous constituents is evaluated using an EPA developed Reference Dose (RfD) derived by the RfD Workgroup, an Acceptable Chronic Intake (AIC) obtained from Health Effects Assessment Documents, or an RfD derived using Office of Drinking Water analyses in support of the MCLG for a chemical. Reference Doses or Acceptable Chronic Intakes are estimates, with uncertainty spanning perhaps an order of magnitude, of the amount of a compound that is not expected to result in adverse noncarcinogenic health effects after chronic exposure of the general population (including sensitive subgroups). The estimate is generally derived by dividing a no-observed-(adverse)-effect-level (NOAEL or NOEL) by an or "uncertainty factor." NOAELs are determined from laboratory or epidemiological toxicity studies. The uncertainty factor (10, 100, or 1,000) is based on the availability of toxicity data: 10 is used if appropriate chronic human data are available; 100 is used if sufficient chronic animal data can be obtained. Thus, the RfD incorporates the surety of the evidence for chronic human health effects. Even if applicable human data exist, the RfD (as diminished by the uncertainty factor) still maintains a margin of safety such that chronic human health effects are not underestimated.

TABLE 6-2

TOXICITY CRITERIA USED FOR INDICATOR CHEMICALS
IN THE RISK ASSESSMENT OF THE VICHEM SITE

<u>Chemical</u>	<u>Cancer Potency Factor</u>			
	<u>Oral</u> <u>(mg/kg/day)⁻¹</u>	<u>Source</u>	<u>Inhalation</u> <u>(mg/kg/day)⁻¹</u>	<u>Source</u>
<u>Carcinogens</u>				
<u>Inorganics</u>				
Arsenic	1.8E+0[A]	[CAG]	1.5E+1[A]	[CAG]
Cadmium	--	--	6.1E+0[B1]	[IRIS]
<u>Organics</u>				
Trichloroethene	1.1E-2[B2]	[CAG]	1.7E-6[B2]	[CAG]

<u>Chemical</u>	<u>Acceptable Chronic Intake</u>			
	<u>Oral</u> <u>(mg/kg/day)</u>	<u>Source</u>	<u>Inhalation</u> <u>(mg/kg/day)</u>	<u>Source</u>
<u>Noncarcinogens</u>				
<u>Inorganics</u>				
Cadmium	5.0E-4 (water)	[Rfd]	---	---
Lead	1.4E-3	[HEA]	---	---
Mercury (inorganic)	2.0E-3	[HEA]	---	---

a) Alphanumerics in brackets represent EPA Weight of Evidence classifications, which are defined as follows:

- Group A - Human Carcinogen. Sufficient evidence from epidemiologic studies to support a casual association between exposure and cancer.
- Group B1 - Probable Human Carcinogen. Limited evidence of carcinogenicity in humans from epidemiologic studies.
- Group B2 - Probable Human Carcinogen. Sufficient evidence of carcinogenicity in animals, inadequate evidence of carcinogenicity in humans.

CAG - Carcinogen Assessment Group, USEPA
 HEA - Health Effects Assessment
 IRIS - Integrated Risk Information System
 Rfd - Reference Dose

Thus, the RfD is an acceptable guideline for evaluation of noncarcinogenic risk, although the associated uncertainties preclude its use for precise risk quantitation. The RfD is expressed in units of mg/kg/day.

- o Cancer Potency Factor - For the assessment of carcinogenic risks, Cancer Potency Factors (CPFs) developed by the USEPA's Carcinogen Assessment Group are used. The CPF for a given chemical is the slope of a line derived from a statistical model which relates risk to dose. The CPF is usually an estimated 95 percent upper-bound confidence limit of the carcinogenic potency of the chemical as observed in an animal study. Occasionally, when human data are available, it may be an estimate closer to the actual slope. In either case, it represents an "upper bound" in the sense that the true potency factor, which is unknown, is believed to be unlikely to exceed the upper-bound risk estimate. In this risk assessment, the CPF used for arsenic (from EPA August, 1988 update to SPHEM) was derived from a human study. CPFs are expressed as the lifetime cancer risk per mg of body weight per day (mg/kg/day)⁻¹. Carcinogenic risks are estimates of the probability, or range of probabilities, that a specific adverse carcinogenic effect will occur.

6.2 IDENTIFICATION OF POTENTIAL EXPOSURE PATHWAYS

This section of the report describes the contaminated media in and around the ViChem facility and identifies several pathways by which humans may be exposed.

6.2.1 Groundwater

Ebasco's groundwater data indicate that shallow and medium depth groundwater, which represent the upper and lower portions of the upper sand aquifer, below and downgradient of the lagoon area, contain high concentrations of arsenic and cadmium. The highest levels of arsenic are found in the medium depth water just downgradient from the lagoon area. In addition, there appears to be a "hot spot" of contamination in the groundwater near EW-13 below chicken coop #3. Although a small amount of arsenic has been detected in deep wells, most of the contamination in the shallow and medium groundwater has not yet reached the deep aquifer (Table 4-5). Significant concentrations of lead, however, have been found in the deep wells.

According to the best information available, groundwater downgradient from the ViChem plant is not presently used as a source of drinking water. However, if a future-use scenario called for the development of these groundwater resources,

exposure to groundwater could occur. Ingestion of groundwater, and showering with groundwater, which can lead to exposure through direct contact and inhalation of volatilized contaminants, were therefore considered as exposure pathways.

6.2.2 Soils

Several indicator chemicals were detected in surface and subsurface soils in various areas in and around the ViChem plant. Arsenic was abundant in surface soils, subsurface soils, lagoon samples, and chicken coop dust, and was the major contaminant of concern.

Surface Soils

ViChem plant soils. Presently, the ViChem site is a functioning facility and the plant property is surrounded by a fence. The likely population exposed to on-site soil contamination should be limited to workers employed at the facility and occasional visitors. Workers may be exposed to surface soils via a number of routes. They can directly contact the contaminated soils and the contamination may be directly absorbed through the skin. Some contaminated soil could be accidentally ingested while eating, drinking or smoking, or by placing hands or other soiled objects in their mouths. Individuals may also inhale airborne contaminated soil or dust. This latter type of exposure is most likely to occur when the soil surface is disturbed, causing an increased amount of soil to be suspended in the air.

In the future, if the ViChem plant were to cease operations and institutional controls were not implemented to restrict access, it is possible that local residents could come into contact with the soils on the plant site. In this scenario, local residents, primarily children, may be exposed to soils by playing or engaging in other activities. Potential routes of exposure would be accidental ingestion, inhalation, and dermal contact. While it is unlikely for residents to contact the site soils at present due to access restrictions, it is prudent to consider this potential exposure scenario in the event that the plant ceased operations and access controls were not maintained. This potential exposure pathway may be relevant in determining cleanup criteria in the event that remediation of the site soils were undertaken.

Residential soils. Generally, low arsenic concentrations were found outside of the plant boundary in specific residential locations at the levels shown in Table 6-3. Residents can be exposed during routine outdoor activities. Like workers, they may be exposed to soils by direct contact, ingestion, or inhalation of contaminated soil. Some children may directly eat soil in a behavior known as pica. Pica children were not considered in this report. Many of the residents in the area surrounding the ViChem plant maintain gardens and consumption of fruits and vegetables grown in contaminated soil may be an additional exposure pathway for these persons. In addition to

VIN 001 1163

TABLE 6-3

CONCENTRATIONS OF INDICATOR CHEMICALS
FOUND AT THE VICHEM SITE

	<u>GEOMETRIC MEAN</u>	<u>ARITHMETIC AVERAGE</u>	<u>MINIMUM</u>	<u>MAXIMUM</u>	<u>SAMPLE SIZE</u>
<u>Residential Soils (mg/kg)</u>					
Arsenic	2.29	6.86	0.40	78.0	17
<u>On-Site Surface Soils (mg/kg)</u>					
Arsenic	4.07	27.9	0.29	650	108
Mercury	0.12	1.08	0.05	11.3	25
<u>Groundwater (Shallow and Intermediate Wells, ug/l)</u>					
Arsenic	281	10200	0.75	394000	153
Cadmium	8.85	279	2.00	9580	82
Lead	3.60	64.0	1.45	3010	54
Trichloroethene	3.84	31.7	1.00	1600	79

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arsenic being taken up into the edible portions of the plant, contaminated soil may cling to the surfaces of leafy vegetables.

Chicken coop dust. High concentrations of arsenic were found in dust samples taken from several chicken coops located near the fence line of the ViChem plant. Chickens are housed in one of the rooms of one of the coops. Some arsenic compounds may be deposited in tissues of chickens due to the consumption of contaminated dust, but organic arsenic compounds (e.g., arsenalic acid) are rapidly removed from the tissues of chickens and excreted mostly in the feces (Overby and Frederickson, 1963). Therefore, the concentration of arsenic in chicken tissues would depend upon the continuous intake of arsenic in their diet. Information regarding the use of the chickens was not available for this study and specific risks associated with this exposure will not be addressed outside of this discussion, although further interviews with local residents would determine whether chicken consumption merits more attention. It should be pointed out that only a small number of chickens were housed in one of the rooms of one of the coops on site (coop #4).

Subsurface soils

Indicator chemicals were found in several samples of subsurface soils. Arsenic was particularly high in samples taken from beneath building #9 in the production area. Subsurface soils should pose no present health risks to humans at the facility. However, if toxic contaminants, especially arsenic, continue to leach into the groundwater, they may present a future health risk.

6.2.3 Lagoon Water and Sediments

Arsenic was found in lagoon water and sediments. Although workers are expected to be near the lagoon area, no direct contact with lagoon water or sediments is expected. The arsine form of arsenic (AsH_3) may volatilize. However, this form is uncommon, except in a highly reducing environment, and therefore exposure to arsenic via inhalation of volatilized compounds is unlikely.

6.2.4 River Water and Sediments

Both water and sediment samples from the Blackwater Branch of the upper Maurice River exhibited arsenic contamination. Risks from contaminated river water and sediments include accidental ingestion of soil and/or water, ingestion of contaminated fish and/or plants, dermal exposure to contaminated water and/or sediments and possible inhalation of volatilized contaminants. A separate remedial investigation addresses these concerns and therefore, these issues will not be discussed further in this report.

6.2.5 Summary

In summary, several routes of potential exposure to chemicals present at the ViChem plant have been identified. These include:

- o Ingestion of groundwater;
- o Inhalation of volatilized components from groundwater during showering;
- o Direct contact with soils;
- o Ingestion of soils;
- o Inhalation of airborne soils;
- o Ingestion of contaminated meat or vegetables;
- o Direct contact with lagoon water; and
- o Inhalation of volatilized components from lagoons.

In the next section, the most likely significant routes of exposure will be identified and rates of contaminant intake by individuals at risk of exposure will be calculated.

6.3 EXPOSURE ASSESSMENT

This step of the risk assessment involves defining the populations at risk and determining the circumstances and levels of exposure. To estimate the levels of exposure for the populations likely to be at risk, several scenarios depicting the activities of plant workers and residents have been constructed. Exposure scenarios for both current-use and future-use conditions are considered. For each scenario, two cases for the intake of contamination were considered for the exposed individuals - an average case and a plausible maximum case. The average case (or most plausible scenario) uses the average exposure scenario assumptions and the geometric mean concentration of the contaminants found as the concentrations of the chemicals in the media. Geometric means were calculated by including all samples and assuming that the value of the non-detected results were equal to half the detection limit. In the discussion that follows, all references to "average" concentration will refer to geometric means. The plausible maximum case (or worst-case scenario) uses the maximum exposure scenario assumptions and the maximum concentrations of the contaminants observed in each medium. The levels of contaminants used in the average and plausible maximum cases are summarized in Table 6-3.

6.3.1 Current-Use Scenario: Exposure of Plant Workers to Contaminated Media

It is believed that workers at the ViChem plant do not use shallow or medium depth groundwater for drinking water. There

was no contamination detected in the deep production well sampled on-site and therefore, even if workers ingest or are otherwise exposed to production well water, it should pose no present health threat.

Workers employed at the ViChem plant are likely to come into direct contact with contaminated soils and dust during normal work activities. In addition, they may inhale contaminated dust, particularly on windy days or when commercial vehicles frequently travel over on-site roads.

Average and maximum exposure scenarios for workers at the ViChem plant were constructed. Table 6-4 presents the equations used to model the exposure pathways, while Table 6-5 presents the parameters derived for worker soil exposure. Under the average exposure scenario workers were assumed to work at the ViChem plant 8 hours a day, 5 days a week, 48 weeks a year, for 5 years; and under the maximum exposure scenario workers retained the same schedule for 20 years. An average adult weight of 70 kg (USEPA, 1986b) was used over the experimental period. For direct soil contact, soil adherence was based on the value of commercial potting soil adhering to hands (1.45 mg/cm²; USEPA, 1986a), which yields a conservative value because potting soil is more likely to adhere to the skin than the sandy soil found at the ViChem site. The skin surface area was calculated by adding the average (50th percentile) surface areas of the hands and arms of adult males. Values were taken from Anderson *et al.* (1985). Once covered with soil, a fraction of arsenic and other inorganic compounds present were assumed to penetrate through the skin. Studies of arsenic (V) exposure from water solutions have shown that not all of the arsenic can be absorbed from water. Even less will be absorbed from soil. In a study of dioxin (TCDD) on soil, Hawley (1985) estimated only 15% of TCDD on soil was available for absorption through the skin. Arsenic on soils would be even less available for dermal absorption. In a dissertation by Winka (1985), experimental studies showed that 43 to 81% of the arsenic in sediment was not extractable into the water. The bioavailability of the arsenic to pass through the skin is expected to be much less than the 15% estimated by Hawley for TCDD. To account for the reduced bioavailability of arsenic from the ViChem soils, the value of percent arsenic and mercury absorption (%ABS) from soils was estimated as 0.9% dermal absorption by workers.

For soil ingestion, 10 mg/day was considered to be the average incidental rate of soil intake and 50 mg/day was considered to be the maximum incidental rate of ingestion for adults (LaGoy, 1987). Gastric absorption was assumed to be 100% for arsenic in both exposure scenarios, and in the maximum exposure for mercury scenario. The most probable case percent absorption factor for mercury was 15%. The suspended soil concentration for the soil inhalation pathway was obtained by using half the nuisance particle level of 10 mg/m³ (ACGIH, 1986). Half of the nuisance particle level was used because the on-site soil was sandy (1/16 mm to 2mm grain size), and therefore would not remain suspended as long as finer grain soils. The rural

TABLE 6-4

CALCULATIONS USED TO DERIVE CHRONIC DAILY INTAKES (CDIs)
OF SELECTED CONTAMINANTS AT THE VICHEM SITE

Carcinogens1. Ingestion (Soil)

$$CDI = SC \text{ (mg/kg)} \times SI \text{ (mg/event)} \times \frac{\% \text{ Absorbed}}{BW \text{ (kg)}} \times \frac{\# \text{ Events}}{365 \text{ days}} \times \frac{\text{Years Exp.}}{70 \text{ years}} \times \frac{10^{-6} \text{ kg}}{\text{mg}}$$

2. Direct Contact (Soil)

$$CDI = SC \text{ (mg/kg)} \times DC \text{ (mg/event)} \times \frac{\% \text{ Absorbed}}{BW \text{ (kg)}} \times \frac{\# \text{ Events}}{365 \text{ days}} \times \frac{\text{Yrs Exp.}}{70 \text{ years}} \times \frac{10^{-6} \text{ kg}}{\text{mg}}$$

3. Inhalation (Soil)

$$CDI = SC \text{ (mg/kg)} \times SSC \text{ (mg/m}^3\text{)} \times IR \text{ (m}^3\text{/event)} \times \frac{\% \text{ Absorbed}}{BW \text{ (kg)}} \times \frac{\# \text{ Events}}{365 \text{ days}} \times \frac{10^{-6} \text{ kg}}{\text{mg}} \times \frac{\text{Yrs Exp.}}{70 \text{ years}}$$

4. Inhalation (Vapors while showering)

$$CDI = WC \text{ (mg/L)} \times IR \text{ (m}^3\text{/event)} \times \frac{\% \text{ Absorbed}}{BW \text{ (kg)}} \times \frac{L}{BV \text{ (m}^3\text{)}} \times \frac{\# \text{ Events}}{365 \text{ days}} \times \frac{\text{Yrs. Exp.}}{70 \text{ yrs}} \times \frac{10^{-6} \text{ kg}}{\text{mg}}$$

5. Ingestion (Groundwater)

$$CDI = WC \text{ (mg/L)} \times DI \text{ (L/day)} \times \frac{\% \text{ Absorbed}}{BW \text{ (kg)}} \times \frac{\text{Yrs. Exp.}}{70 \text{ years}}$$

Non-Carcinogens1. Ingestion (Soil)

$$CDI = SC \text{ (mg/kg)} \times SI \text{ (mg/event)} \times \frac{\% \text{ Absorbed}}{BW \text{ (kg)}} \times \frac{\# \text{ Events}}{365 \text{ days}} \times \frac{10^{-6} \text{ kg}}{\text{mg}}$$

2. Direct Contact (Soil)

$$CDI = SC \text{ (mg/kg)} \times DC \text{ (mg/event)} \times \frac{\% \text{ Absorbed}}{BW \text{ (kg)}} \times \frac{\# \text{ Events}}{365 \text{ days}} \times \frac{10^{-6} \text{ kg}}{\text{mg}}$$

3. Inhalation (Soil)

$$CDI = SC \text{ (mg/kg)} \times SSC \text{ (mg/m}^3\text{)} \times IR \text{ (m}^3\text{/event)} \times \frac{\% \text{ Absorbed}}{BW \text{ (kg)}} \times \frac{\# \text{ Events}}{365 \text{ days}} \times \frac{10^{-6} \text{ kg}}{\text{mg}}$$

4. Inhalation (Vapors while showering)

$$CDI = WC \text{ (mg/L)} \times IR \text{ (m}^3\text{/event)} \times \frac{\% \text{ Absorbed}}{BW \text{ (kg)}} \times \frac{L}{BV \text{ (m}^3\text{)}} \times \frac{\# \text{ Events}}{365 \text{ days}} \times \frac{10^{-6} \text{ kg}}{\text{mg}}$$

TABLE 6-4 (Cont'd)

CALCULATIONS USED TO DERIVE CHRONIC DAILY INTAKES (CDIs)
OF SELECTED CONTAMINANTS AT THE VICHEM SITE

5. Ingestion (Groundwater)

$$CDI = WC \text{ (mg/l)} \times DI \times \frac{\% \text{ Absorbed}}{BW \text{ (kg)}}$$

DEFINITIONS:

1. CDI = Chronic Daily Intake (mg/kg-day)
2. SC = Soil Concentration (mg/kg)
3. SI = Soil Ingestion Rate (mg/event)
4. DC = Dermal Contact Rate (mg/event)
5. SSC = Suspended Soil Concentration (mg/m³)
6. IR = Inhalation Rate (m³/event)
7. BV = Bathroom Volume (m³)
8. L = Liters of water used
9. WC = Water Concentration (mg/L)
10. DI = Daily Ingestion Rate L/day)
11. BW = Body Weight (Kg)
12. 70 Years = Average Adult Lifetime
13. % Absorbed = Percent Taken Up By Body

NOTE: Parameters values are given in Tables 6-5 through 6-7.

TABLE 6-5

ASSUMPTIONS USED TO ESTIMATE EXPOSURES
TO WORKERS VIA SOILS AT THE VICHEM SITE

<u>Parameter</u>	<u>Most Probable Case</u>	<u>Worst Case</u>
Frequency	240 events/yr (5 d/wk for 48 weeks)	240 events/yr (5 d/wk for 48 weeks)
Duration	5 years	20 years
Average Weight Over Exp. Period	70 kg	70 kg
<u>Soil contact:</u>		
Soil Contact Rate	4640 mg/day	4640 mg/day
Skin Surface Area Exp. ⁽¹⁾	0.32 m ²	0.32 m ²
Soil Adherence ⁽²⁾	14500 mg/m ²	14500 mg/m ²
Absorption (%)		
Dermal Absorption	0.9	0.9
<u>Soil ingestion:</u>		
Ingestion Rate ⁽³⁾	10 mg/day	50 mg/day
Absorption (%)		
As	100	100
Hg	15	100
<u>Soil inhalation:</u>		
Suspended Soil Concentration ⁽⁴⁾	0.017 mg/m ³	5.0 mg/m ³
Inhalation Rate	22.4 m ³ /event	39.6 m ³ /event
Breathing Rate ⁽²⁾	2.8 m ³ /hr ² (moderate activity for 8 hrs.)	2.8 m ³ /hr (moderate activity for 4 hrs.) 7.1 m ³ /h (heavy activity for 4 hrs.)
Duration of event	8 hrs	8 hrs.
Absorption (%) Lung Absorption ⁽⁵⁾	30	80
⁽¹⁾ Anderson et al., 1985 ⁽²⁾ USEPA, 1986a ⁽³⁾ LaGoy, 1987 ⁽⁴⁾ ACGIH, 1986 and USEPA, 1982. ⁽⁵⁾ Holland et al., 1959 and USEPA, 1984		

background level of 0.017 mg/m³ (USEPA, 1982) was used for the average scenario. The division of activities that workers would be involved in during the day was taken into account when calculating the inhalation rate. Workers were assumed to be involved in heavy activity four hours a day and moderate activity four hours a day for the maximum exposure scenario, and were assumed to engage in eight hours of moderate activity for the average exposure scenario. A lung absorption factor of 30% for the average exposure scenario (USEPA, 1984) and 80% for the maximum exposure scenario was used based on a study of arsenic aerosols (Holland, et al., 1959).

Workers are expected to work around, but not within, the lagoon area. Therefore, direct contact with contaminated lagoon water and/or sediments is unlikely. The lagoon water contains arsenic, but the gaseous form of arsenic is rarely found, and even if present, the majority of arsenic would probably volatilize rapidly (Subsection 5.1.6). Lagoon-related pathways will not be evaluated further.

6.3.2 Current-Use Scenario: Exposure of Residents Using Public Water

Arsenic was detected in generally low concentrations in soil samples taken from residences just outside the plant boundary. Residents may be exposed to soils during normal outdoor activities, such as play or gardening, through direct dermal contact, and through ingestion.

An age-specific exposure model was used to calculate lifetime residential exposure to contaminated soil. This model attempted to provide a more realistic exposure estimate that considered various physical and exposure parameters at different life stages. The sum of risks at all life stages was calculated for a total lifetime risk.

For the most probable case scenario, the number of days spent outdoors was considered to be two days/week for four months (32 days) for infants and adults and four days/week for four months (64 days) for all age classes of children. The worst cases for these two groups of individuals were considered to be two days/week for eight months (64 days) and four days/week for eight months (128 days) per year, respectively. For all age groups one hour/day was considered to be the average exposure and four hours/day was considered to be the maximum plausible exposure.

Soil ingestion rates were based on LaGoy (1987). Children between the ages of two to six years had the highest soil ingestion rates (200 mg/day and 80 mg/day for worst and most plausible cases, respectively) with soil ingestion decreasing as children mature. The soil ingestion rates of infants were considered to be 100 mg/day and 50 mg/day for the worst and most plausible cases, respectively. Adults were assumed to ingest 1 mg of soil daily under average conditions, and 50 mg/day under worst-case conditions.

For direct contact with soil, exposed surface areas were calculated based on the 50th percentile surface areas of each age group taken from Anderson, et al. (1985). For the worst case scenario, the surface areas of the hands, arms, and legs were added for children up to age 18 and hands, forearms and legs were added for adults. For the most plausible case scenario the hands and arms were added for children up to 18 years of age and the hands and forearms were added for adults. The most plausible case soil deposition rate was 0.5 mg/cm², which was calculated by pressing a 21.5 cm² tape against the hands of children after they had played outdoors (Lepow, 1975). The worst-case soil deposition rate used was 1.45 mg/cm² based on the USEPA (1986a) soil adherence value for potting soil, which generally has greater adherence than the sandy soil found on the ViChem site.

Once covered with soil, once again, only a fraction of the arsenic in the soil was assumed to penetrate through the skin. As discussed in Subsection 6.3.1, the majority of arsenic in the soil is not bioavailable. To account for the reduced bioavailability of arsenic from the soil, values of percent arsenic absorption (%ABS) from soil were estimated as: 1.8% arsenic dermal absorption by children under ten and 0.9% arsenic dermal absorption by adults.

Inhalation of soil was also considered for all age groups. The suspended soil concentration used for both scenarios was 0.017 mg/m³ based on a representative rural ambient airborne particulate concentration (USEPA, 1982). This value was used for both scenarios because no extensive disturbance, such as heavy commercial vehicles, were expected to be found in residential areas. Inhalation rates for each age group were taken from the Superfund Exposure Assessment Manual (EPA, 1986a) and Anderson, et al., (1985). Worst case soil inhalation rates were calculated using heavy activity rates (i.e., vigorous exercise) for four hours/day and most probable case soil inhalation rates were calculated using moderate activity rates (e.g., heavy work, climbing stairs, and performance of repairs) for one hour per day. When inhalation rates were not available for certain age classes, estimates were made based on inhalation rates for the neighboring age classes.

Assumptions used for all exposure pathways are summarized in Table 6-6.

Although exposure through contaminated vegetables is possible, this exposure pathway will not be considered in detail because the residential contamination appears to be somewhat localized (see Section 4) and probably does not pose a threat to the majority of the area residents. Levels of contaminants in chicken coops were high, and if it is determined that residents consume poultry from these coops, this pathway should be evaluated further.

TABLE 6-6

PARAMETERS FOR RESIDENTIAL EXPOSURES TO SOIL**Physical Parameters**

<u>Population</u>	<u>Age</u>	<u>Body Weight⁽¹⁾</u> <u>kg</u>	<u>Surface Area⁽¹⁾</u> <u>cm²</u>	
				Worst Case Most Probable Case
Infant	0-1	8.95	9.00E+2	4.00E+2
Young Child	2-6	17.0	3.14E+3	1.33E+3
Child	7-10	28.4	4.60E+3	1.78E+3
Child	11-14	45.3	6.98E+3	2.56E+3
Child	15-17	59.7	9.26E+3	3.62E+3
Adults	18-70	70.0	4.05E+3	1.98E+3

Exposure Parameters

<u>Population</u>	<u>Days Outdoors</u>		<u>Soil Ingestion⁽²⁾</u> <u>Rate g/day</u>		<u>Inhalation^(1,3)</u> <u>Rates m³/hr</u>		<u>Years Exposure</u>
	Worst Case	Most Probable Case	Worst Case	Most Probable Case	Worst Case	Most Probable Case	
Infant (0-1)	64	32	1.00E-01	5.00E-02	0.13	0.10	2
Young Child (2-6)	128	64	2.00E-01	8.00E-02	3.3	2.7	5
Child (7-10)	128	64	1.00E-01	5.00E-02	3.3	2.7	4
Child (11-14)	128	64	5.00E-02	1.00E-02	4.0	2.7	4
Child (15-17)	128	64	5.00E-02	1.00E-02	5.0	2.7	3
Adults(18-70)	64	32	5.00E-02	1.00E-02	6.0	2.6	52

% AbsorbenceIngestion: 100% Ingestion⁽⁴⁾Inhalation: 30% Most probable case, 80% worst case⁽⁵⁾Direct Contact: 1.8% up to 10 yrs, 0.9% 10 years to adult⁽⁶⁾Soil Deposition RatesWorst Case 1.45 mg/cm²⁽³⁾Most Probable Case 0.5 mg/cm²⁽⁷⁾Suspended soil concentration 0.017 mg/m³⁽⁸⁾Assume: 1 hr/day most probable case exposure
4 hrs/day worst case exposure

TABLE 6-6 (Cont'd)

PARAMETERS FOR RESIDENTIAL EXPOSURES TO SOIL

- (1) Anderson et al., 1985
- (2) LaGoy, 1987
- (3) USEPA, 1986a
- (4) USEPA, 1984
- (5) USEPA, 1984 and Holland et al., 1959
- (6) Hawley, 1985
- (7) Lepow, 1975
- (8) USEPA, 1982

6.3.3 Future-Use Scenario: Exposure of Residents Using Private Wells

According to the best information available, no residents are using groundwater downgradient of the ViChem plant. However, if these groundwater resources were developed in the future, residents using private wells downgradient of the ViChem plant would be exposed through direct contact, ingestion, and inhalation of contaminated soils in the manner discussed in Subsection 6.3.2, and would additionally be exposed to contaminated groundwater. Additional exposures may result from the ingestion of contaminated groundwater and the inhalation of volatilized contaminants from water while showering. Risks resulting from absorption of contaminants via dermal contact while showering are considered slight in comparison to inhalation risks (Foster and Chrostowski, 1987), and are therefore not calculated here.

To calculate the dose of contamination received via showering, several assumptions were made. The assumption made for the worst case was a shower lasting 20 minutes and using 190 liters of water, (Andelman, 1985). In contrast, the average case scenario used half the values, the average shower duration was 10 minutes, and 95 liters of water were used. Only trichloroethene (TCE) was evaluated for this pathway, because it was the only indicator compound with a high probability of volatilization. One hundred percent volatilization was assumed for both cases. The worst-case scenario had 100% TCE absorption, whereas the maximum plausible case scenario had 50% TCE absorption. The bathroom was assumed to be 12 m³ (USEPA, 1986b), and the model did not take any air movement into account. Both children and adults were assumed to shower/bathe under the same conditions. Inhalation rates were taken from the Superfund Exposure Assessment Manual (USEPA, 1986). Worst-case inhalation values assumed individuals engaging in light activity. Most plausible case inhalation estimates were taken from resting inhalation rates. Once again, as in soil inhalation, when inhalation rates were not available for particular age groups, a neighboring value, or a mean between neighboring values, were used. Inhalation while showering assumptions are given in Table 6-7.

To calculate water ingestion rates, the standard water consumption rates of two liters/day for a 70 kg adult and children older than 10 years, and one liter/day for children up to 10 years of age were used for the worst-case scenario. A 100% gastric absorption efficiency was assumed for all compounds. For the most probable case scenario, 100% absorption was assumed for arsenic and TCE (EPA, 1983; 1984). A 15% absorption efficiency was assumed for lead and cadmium for adults and children older than 10 years (Chamberlain, 1978) while a 50% absorption efficiency was assumed for children less than 10 years.

Groundwater exposure assumptions are listed in Table 6-7.

TABLE 6-7

PARAMETERS FOR RESIDENTIAL EXPOSURES TO GROUNDWATER**Physical Parameters**

<u>Population</u>	<u>Age</u>	<u>Body Weight⁽¹⁾</u> <u>kg</u>	<u>Years Exposure</u>
Infant	0-1	8.95	2
Young Child	2-6	17.0	5
Child	7-10	28.4	4
Child	11-14	45.3	4
Child	15-17	59.7	3
Adults	18-70	70.0	52

Exposure Parameters

<u>Population</u>	<u>Water Ingestion⁽²⁾</u> <u>Rate l/day</u>		<u>Inhalation^(1,3)</u> <u>Rates m³/hr</u>	
	<u>Worst Case</u>	<u>Most Probable Case</u>	<u>Worst Case</u>	<u>Most Probable Case</u>
Infant (0-1)	1	1	0.13	0.1
Young Child (2-6)	1	1	1.3	0.4
Child (7-10)	1	1	1.7	0.4
Child (11-14)	2	2	1.7	0.6
Child (15-17)	2	2	1.5	0.6
Adults (18-70)	2	2	1.3	0.6

% Absorbence

Ingestion: 100% Arsenic⁽⁴⁾ and TCE⁽⁵⁾ most probable and worst case
 100% Worst case for lead and cadmium for all individuals
 50% Lead and cadmium - children under 10 years⁽⁶⁾ most probable case
 15% Lead and cadmium - adult and children over 10 years most probable case
 Inhalation: TCE 50% most probable case,
 100% worst case

Length of Shower/Bath: 10 minutes most plausible case, 20 minutes worst case

Liters of Water Used per Shower/Bath⁽⁸⁾: 95 liters most plausible case,
 190 liters worst case

(1) Anderson et al., 1985

(2) USEPA, 1986b

(3) USEPA, 1986a

(4) USEPA, 1984

(5) USEPA, 1983

(6) Chamberlain, 1978

(7) Hammond, 1982

(8) Andelman, 1985

6.4 ESTIMATION OF POTENTIAL HEALTH RISKS

The last step of a risk assessment involves the comparison of the daily intakes rates assumed for the populations at risk with health-based criteria to determine the risks posed to human health, and the calculation of lifetime cancer risks from carcinogenic pollutants. In this section, cancer and noncancer health risks associated with exposure to the chemicals present at the ViChem plant site are assessed. The assumptions regarding the behavior of the populations at risk described in the previous section are used to estimate human exposure. This exposure is expressed in the form of a chronic daily intake, or CDI, which is the amount of a substance taken into the body per unit weight per unit of time, or mg/kg/day. This intake level will then be compared to the toxicological criteria described below to determine whether current levels of exposure pose a threat to human health.

To assess noncarcinogenic risks associated with exposure, the CDI of a chemical exposure rate/population is compared to its reference dose. The risk is presented as the ratio of the chronic daily intake to the reference dose (CDI:Rfd). The sum of all CDI:Rfd ratios of chemicals being considered is referred to as the Hazard Index. The Hazard Index (HI) is a useful reference point for gauging the potential adverse noncarcinogenic health effects of an exposure. In general, an HI of greater than or equal to one indicates that an adverse noncarcinogenic health effect could potentially occur, while an HI of less than one indicates that an adverse noncarcinogenic effect is unlikely to occur. It should not be assumed that all indices less than one are acceptable and those greater than one are unacceptable because there is approximately one order of magnitude of uncertainty associated with the estimates of the CDI and Rfd. In addition, hazard indices greater than one may reflect risks associated with one or a few pollutants, or they may reflect CDI: Rfd ratios of less than one for all individual pollutants, which may affect different organ systems. In either case, the HI values need to be interpreted cautiously.

To assess carcinogenic risks associated with exposure, the CDI for a particular chemical is multiplied by its cancer potency factor (CPF) to yield an upper bound excess lifetime cancer risk estimate. For cancer risks greater than 10^{-2} , the Risk = $1 - \exp. (-CDI \times CPF)$, (USEPA, 1986b).

Values of Rfds and CPFs used in this assessment are given in Table 6-2.

6.4.1 Workers

For the purposes of this assessment, workers were considered to be exposed to surface soils by direct contact, ingestion, and inhalation. Using the intake rates derived using most plausible case and worst case exposure assumptions coupled with geometric means and maximum concentrations of the indicator chemicals, respectively, upper bound excess lifetime cancer risks of 2×10^{-7} and 4×10^{-3} were calculated for worker exposure under the most plausible and worst-case conditions (Table 6-8). When the maximum exposure scenario was used all pathways exceeded the target level for lifetime cancer risks of 10^{-6} (one in a million excess cases of cancer). Using the most plausible case assumptions, none of the soil pathways exceeded the target risk level.

Noncarcinogenic effects of mercury in the soil did not exceed a CDI:RfD ratio of 1.0 for either scenario. Using the worst case ingestion, inhalation and direct contact pathways yielded a total value of 1×10^{-2} , while the hazard index decreased to 2×10^{-5} using the most plausible case scenario. Therefore, noncancer risks are not likely to be significant for these pathways.

6.4.2 Residents

Present-Day Scenario: Exposure of Residents Using Public Water

Current risks to residents around the ViChem plant area were calculated from ingestion, inhalation, and direct contact of contaminated soils. Most plausible case scenarios using geometric mean concentrations in the residential soils did not yield risks above the target risk level of 10^{-6} for arsenic via any of the three individual exposure pathways (Table 6-9). The total lifetime risk from all exposure pathways for the most plausible case calculations was 6×10^{-7} , which is less than the target risk level of 10^{-6} . The individual pathways of soil ingestion and dermal contact exceeded the target risk level of 10^{-6} using the worst case scenarios for all age groups, except for dermal exposure for infants which was equal to 1×10^{-6} . The soil inhalation pathway did not exceed the target risk level for any age group under the worst case scenario, although the total worst-case inhalation risk was equal to 1×10^{-6} . The total excess risk to an individual exposed over a lifetime to the worst-case scenario was 1×10^{-4} , or one additional cancer case in 10,000 people. The total most plausible risk was 6×10^{-7} , or six additional incidents of cancer per ten million persons exposed.

If residents inadvertently consume additional soil on garden produce, risks would increase in proportion to the amount of additional soil consumed.

TABLE 6-8

CARCINOGENIC AND NONCARCINOGENIC RISKS TO WORKERS
FROM CONTAMINATED SOIL AT THE VINELAND SITE

Excess Lifetime Cancer Risks	Soil Ingestion		Soil Inhalation		Dermal Contact		Total	
	Worst Case	Most Plausible Case	Worst Case	Most Plausible Case	Worst Case	Most Plausible Case	Worst Case	Most Plausible Case
Arsenic								
Workers	2x10 ⁻⁴ *	5x10 ⁻⁸	4x10 ⁻³ *	5x10 ⁻⁹	1x10 ⁻⁴ *	1x10 ⁻⁷	4x10 ⁻³ *	2x10 ⁻⁷
Percent of Total Risk	4.7%	32.2%	93.0%	3.2%	23%	64.5%	100%	100%
<u>Noncarcinogenic Risks (CDI:Rfd)</u>								
Mercury	3x10 ⁻³	7x10 ⁻⁸	8x10 ⁻³	3x10 ⁻⁸	2x10 ⁻³	2x10 ⁻⁵	1x10 ⁻²	3x10 ⁻⁵

* Exceeds target risk level of 10⁻⁶ for carcinogenic compounds.

TABLE 6-9

CARCINOGENIC RISKS TO RESIDENTS VIA EXPOSURE TO ARSENIC IN SOIL

	Soil Ingestion		Soil Inhalation		Dermal Contact		Total	
	Worst Case	Most Plausible Case	Worst Case	Most Plausible Case	Worst Case	Most Plausible Case	Worst Case	Most Plausible Case
Infant Age 0-1	8x10 ⁻⁶ *	6x10 ⁻⁸	5x10 ⁻⁹	5x10 ⁻¹²	1x10 ⁻⁶	8x10 ⁻⁹	9x10 ⁻⁶ *	7x10 ⁻⁸
Young Child Age 2-6	4x10 ⁻⁵ *	2x10 ⁻⁷	3x10 ⁻⁷	3x10 ⁻¹⁰	1x10 ⁻⁵ *	7x10 ⁻⁸	6x10 ⁻⁵ *	3x10 ⁻⁷
Child Age 7-10	1x10 ⁻⁵ *	7x10 ⁻⁸	1x10 ⁻⁷	2x10 ⁻¹⁰	8x10 ⁻⁶ *	5x10 ⁻⁸	2x10 ⁻⁵ *	1x10 ⁻⁷
Child Age 11-14	3x10 ⁻⁶ *	9x10 ⁻⁹	1x10 ⁻⁷	1x10 ⁻¹⁰	4x10 ⁻⁶ *	2x10 ⁻⁸	7x10 ⁻⁶ *	3x10 ⁻⁸
Child Age 15-17	2x10 ⁻⁶ *	5x10 ⁻⁹	8x10 ⁻⁸	6x10 ⁻¹¹	3x10 ⁻⁶ *	2x10 ⁻⁸	5x10 ⁻⁶ *	3x10 ⁻⁸
Adult Age 18-70	1x10 ⁻⁵ *	4x10 ⁻⁸	7x10 ⁻⁷	4x10 ⁻¹⁰	1x10 ⁻⁵ *	7x10 ⁻⁸	2x10 ⁻⁵ *	1x10 ⁻⁷
TOTAL	7x10 ⁻⁵ *	4x10 ⁻⁷	1x10 ⁻⁶	1x10 ⁻⁹	4x10 ⁻⁵ *	2x10 ⁻⁸	1x10 ⁻⁴ *	6x10 ⁻⁷
Percent of Total Risk	63%	66.6%	0.9%	0.1%	36.0%	33.3%	100%	100%

* Exceeds target risk level of 10⁻⁶

Future-Use Scenario: Exposure of Residents Using Private Wells Downgradient of the ViChem Plant

Use of groundwater from the ViChem plant site could pose several health risks to the local population. Noncarcinogenic risks of groundwater ingestion exceeded a CDI:RfD ratio of one for the independent and combined effects of lead and cadmium in worst case conditions for adults and children (Table 6-10). At average concentrations and exposure conditions, lead fell one order of magnitude below a CDI:RfD ratio of one, and the cadmium CDI:RfD ratio equalled one for infants, but fell below one for the remainder of age classes.

Potential carcinogenic risks from groundwater ingestion for all age groups (Table 6-11) exceeded the target risk level of 10^{-6} for arsenic using worst-case and most plausible case assumptions. In the worst-case calculations for arsenic, the groundwater ingestion scenarios predict cancer risks approaching 1.0. Trichloroethene carcinogenic risks from drinking the water were calculated to be greater than the target level of 10^{-6} for all age groups under worst case conditions, and for adults under most plausible case conditions.

Inhalation of trichloroethene vapors while showering (Table 6-12) did not exceed the target risk level of 10^{-6} for any age group when either scenario was used. Volatilization of lead, arsenic, and cadmium in the shower was not considered, since it is unlikely that these metals would volatilize.

If local residents that presently use the public water supply were to switch to shallow groundwater, they would experience similar risks to the future-use scenario of residents using private wells. Risks could decrease in the future if arsenic is leached from the on-site soil by groundwater flow and transported to the Blackwater Branch.

Summary of Risks

Arsenic levels in soils pose potential health risks to workers on site and residents nearby under worst case exposure scenarios. These scenarios assume both increased exposure and a higher concentration of arsenic in soil than the most plausible case scenario. Under the most plausible scenario, both the workers and residential soil risks were less than 10^{-6} , being 2×10^{-7} and 6×10^{-7} , respectively.

If contaminated groundwater is ingested, the health risks increase substantially. Under worst-case conditions, there is the potential for noncarcinogenic health risks from lead and cadmium and carcinogenic health risks from arsenic and TCE. If the most plausible case conditions are met, which primarily consist of decreased levels of groundwater contamination and lower gastric absorption levels for some compounds, then risks still remain above target levels for lead, arsenic and TCE. Showering with contaminated groundwater should not result in any excessive risks.

TABLE 6-10

NONCARCINOGENIC RISKS ASSOCIATED WITH INGESTION OF CONTAMINATED
GROUNDWATER AT THE VINELAND CHEMICAL SITE

	Lead		Cadmium		Total		Hazard Index Most Plausible Case
	Worst Case	Most Plausible Case	Worst Case	Most Plausible Case	Worst Case	Most Plausible Case	
Infant Age 0-1	2×10^2 **	1×10^{-1}	2×10^3 **	1×10^0	2×10^3 **	1×10^0	1×10^0
Young Child Age 2-6	1×10^2 **	3×10^{-2}	1×10^3 **	2×10^{-1}	1×10^3 **	2×10^{-1}	2×10^{-1}
Child Age 7-10	8×10^1 **	2×10^{-2}	7×10^2 **	1×10^{-1}	8×10^2 **	1×10^{-1}	1×10^{-1}
Child Age 11-14	9×10^1 **	2×10^{-2}	8×10^2 **	1×10^{-1}	9×10^2 **	1×10^{-1}	1×10^{-1}
Child Age 15-17	7×10^1 **	1×10^{-2}	6×10^2 **	9×10^{-2}	7×10^2 **	1×10^{-1}	1×10^{-1}
Adult Age 18-70	6×10^1 **	1×10^{-2}	5×10^2 **	8×10^{-2}	6×10^2 **	9×10^{-2}	9×10^{-2}

** Value exceeds Chronic Daily Intake: Reference Dose ratio of one.

TABLE 6-11

CARCINOGENIC RISKS ASSOCIATED WITH INGESTION OF CONTAMINATED
GROUNDWATER AT THE VINELAND CHEMICAL SITE

	Arsenic		Trichloroethene		Total Risk	
	Worst Case	Most Plausible Case	Worst Case	Most Plausible Case	Worst Case	Most Plausible Case
Infant Age 0-1	$9 \times 10^{-2} *$	$2 \times 10^{-3} *$	$6 \times 10^{-5} *$	2×10^{-7}	$9 \times 10^{-2} *$	$2 \times 10^{-3} *$
Young Child Age 2-6	$9 \times 10^{-2} *$	$2 \times 10^{-3} *$	$7 \times 10^{-5} *$	2×10^{-7}	$9 \times 10^{-2} *$	$2 \times 10^{-3} *$
Child Age 7-10	$8 \times 10^{-2} *$	$1 \times 10^{-3} *$	$4 \times 10^{-5} *$	1×10^{-8}	$8 \times 10^{-2} *$	$1 \times 10^{-3} *$
Child Age 11-14	$8 \times 10^{-2} *$	$1 \times 10^{-3} *$	$4 \times 10^{-5} *$	1×10^{-7}	$8 \times 10^{-2} *$	$1 \times 10^{-3} *$
Child Age 15-17	$6 \times 10^{-2} *$	$7 \times 10^{-4} *$	$3 \times 10^{-5} *$	6×10^{-8}	$6 \times 10^{-2} *$	$7 \times 10^{-4} *$
Adult Age 18-70	$9.9 \times 10^{-2} *$	$1 \times 10^{-2} *$	$4 \times 10^{-4} *$	1×10^{-6}	$9.9 \times 10^{-2} *$	$1 \times 10^{-2} *$
TOTAL	$9.9 \times 10^{-2} *$	$2 \times 10^{-2} *$	$6 \times 10^{-4} *$	$2 \times 10^{-6} *$	$9.9 \times 10^{-2} *$	$2 \times 10^{-2} *$

* Exceeds target excess cancer risk level of 10^{-6}

TABLE 6-12

INHALATION OF TRICHLOROETHENE (TCE) WHILE
SHOWERING/BATHING USING CONTAMINATED
GROUNDWATER FROM THE VINELAND CHEMICAL SITE

	TCE Inhalation	
	<u>Worst Case</u>	<u>Most Plausible Case</u>
Infant Age 0-1	6×10^{-15}	1×10^{-18}
Young Child Age 2-6	8×10^{-14}	8×10^{-18}
Child Age 7-10	5×10^{-14}	4×10^{-18}
Child Age 11-14	3×10^{-14}	3×10^{-18}
Child Age 15-17	2×10^{-14}	2×10^{-18}
Adult Age 18-70	2×10^{-13}	3×10^{-17}
Total	4×10^{-13}	5×10^{-17}

6.5 UNCERTAINTY IN RISK ESTIMATES

The procedures used to develop the estimates of risk for exposure to soil and groundwater at the ViChem site involve many analytical assumptions, models and procedures that introduce uncertainty into those estimates. In this section, the three prime sources of uncertainty in these estimates will be addressed. These are: 1) sampling and analytical error, 2) exposure and dose estimation models, and 3) toxicologic models.

6.5.1 Sampling and Analytical Error

All of the estimates of exposure, doses and risks developed in this assessment ultimately depend upon the chemical sampling and analytical results obtained during the RI. They therefore reflect the limitations and inherent uncertainties of these data. The first source of uncertainty in the results are the errors associated with the procedures employed to select and gather samples for chemical analyses. Two major concerns in any assessment are whether there are enough samples to adequately characterize concentrations in the media of concern, and whether the samples are collected in a manner and at locations that are representative of the areas being characterized.

Complete groundwater and soil sampling programs were designed and implemented in order to eliminate as much uncertainty as possible and define the nature and extent of contamination with a greater degree of confidence. Groundwater was sampled from 36 monitoring wells installed by Ebasco, 11 existing ViChem monitoring wells, the plant's production well, and the deep monitoring well installed by Hart in the lagoon area. Two rounds for groundwater samples were obtained. All samples were analyzed for dissolved arsenic, HSL inorganics (unfiltered), HSL volatiles, and pesticides/PCBs. In addition, 25% of all samples were analyzed for acid base/neutral extractable organics. A total of 25 on-site surface soil samples were analyzed for HSL inorganics, and an additional 86 samples were analyzed for arsenic only. In addition, 67 subsurface samples were analyzed for HSL inorganics and 336 subsurface samples were analyzed for arsenic. Seventeen residential samples, taken from residential yards bordering the site and nonresidential woodlands around the site in all directions, were analyzed for arsenic only. This comprehensive soil and groundwater sampling provides a reliable data base, which minimizes the uncertainty present in any field sampling program.

The chemical analyses performed and used in the risk assessment were done under the Contract Laboratory Program (CLP). This program ensures that samples undergo a complete series of quality control measures in a certified laboratory. After laboratory analysis was completed, data were fully validated using rigorous quality control measures to ensure the reliability of the results. These measures provide additional confidence in the data.

In regard to arsenic and mercury, the lack of data concerning ionic and chemical speciation also needs to be addressed in any discussion of uncertainty. For both of these metals, only total inorganic concentration data were available. Both of the pollutants can exist in more than one chemical species in the environment, and these species differ in both their environmental fate and their toxicologic properties. Using the total inorganic arsenic and mercury analyses, therefore, involves making assumptions about speciation that also introduces uncertainty into the assessment.

6.5.2 Uncertainty in Exposure and Dose Assessment Model

In this analysis, estimates of pollutant exposures and doses were made using models and assumptions which describe the environmental fate and distribution of contaminants, the behavior of potential contaminant receptors, and the biological interactions between contaminated media and receptors resulting in contaminant uptake. For the soil and groundwater pathways, exposure point concentrations were estimated directly from the analytical data, and therefore depend heavily upon the quality and representativeness of those data and the methods used to summarize them for the exposure assessment. The quality of these data have been discussed above, and the methods used to summarize the data (maximum and geometric mean) are appropriate to the development of worst-case and representative pollutant levels where the distribution of the data is not well-characterized, but expected to be positively skewed from a Gaussian distribution.

Other factors that introduce uncertainty into the exposure estimates include behavioral assumptions (e.g., days spent outdoors, hours/day exposed, proportion of lifetime exposed), exposure-related factors (skin deposition of pollutants, soil ingestion, etc.) and intake factors (matrix-specific bioavailability, dermal and gastrointestinal absorption factors). In particular, the inhalation models had some elements of uncertainty. For soil inhalation, conservative estimates were made in regard to particulate concentrations in air, inhalation rates, lung absorption, and the duration of the event. Wind direction and speed were not considered. In the shower inhalation model, volatilization of TCE was considered to be 100% and air movement in the bathroom was not considered. In many cases, it is difficult to judge the direction or magnitude of the bias that may be introduced into dose estimates by specific models using a parameter value selected. On the whole, however, it is probable that the overall effect of the analytical assumptions made is moderate to very "conservative". That is, values are chosen that are likely to somewhat overstate rather than understate risks. The rationale for this approach is to allow a relatively high degree of certainty to be achieved so that the worst-case exposure scenario actually represents a plausible upper bound on exposures and risks.

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6.5.3 Uncertainty in Toxicological Models and Parameters

The final sources of potential uncertainty in the risk estimate are the models used to characterize the toxicologic properties of the indicator chemicals. Throughout this analysis, EPA-approved models and toxicologic parameters (RfDs and CPFs) have been used for both carcinogenic and noncarcinogenic effects. In both cases there are uncertainties built into the analyses by virtue of the assumptions used to define the models and derive the parameters.

The carcinogenic risk model used assumes a linear non-threshold model of cancer induction, which takes as its slope parameter the CPF derived as the upper 95% confidence limit of the dose-response slope derived using data from specific animal or epidemiologic studies of cancer induction. As such, the value also tends to be "conservative", giving an upper estimate of the true slope parameter. In the case of arsenic, the data used to develop the CPF are derived from an epidemiologic study of a population in Taiwan exposed to primarily pentavalent arsenic in drinking water. Since no speciation data are available for arsenic in any of the media sampled in this investigation, it is not clear how closely the speciation is similar to that for which the CPF was derived. The magnitude of this potential bias cannot be estimated.

The basis for the assessment of noncancer risks used in this analysis is the comparison of daily average doses (CDIs) to acceptable chronic intake values (AICs), with CDI:AIC values exceeding 1.0 being indicative of potential health effects. All the AIC values used in this analysis are RfDs (reference doses) derived by EPA using uncertainty factors applied to the results of animal or human studies that demonstrate No Adverse Effects Levels (NOAELs) or Lowest Adverse Effect Levels (LOAELs). The net effect of the use of uncertainty factors tends towards conservatism; the RfDs represent values below which average daily doses are very unlikely to have an adverse effect on even the most sensitive population. They do not necessarily represent doses above which adverse effects will definitely be seen.

For both carcinogenic and noncarcinogenic effects, the assumption of multiple pathways and multiple pollutant additivity of effects is made in this analysis. The multipathway assumption has a firm basis in theory. The risk associated with exposure to a specific pollutant should depend upon the total dose reaching the bloodstream, independent of the route of administration, unless there is some special consideration regarding absorption, disposition, or metabolism that determines otherwise. Where such factors exist, they can be taken into account (as is done in this analysis for ingested vs. inhaled arsenic).

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The assumption of additivity for multiple pollutant exposures is less firmly supported by theory for both carcinogenic and noncarcinogenic effects. However, this assumption is not likely to have a significant impact for carcinogenic exposure since for essentially all of the routes of exposure, the total risks are dominated by one pollutant (arsenic).

6.5.4 Summary of Uncertainty

The quantitative estimates of risk are likely to be quite uncertain, since their derivation involves the interpretation of inherently uncertain analytical data, and the use of imprecise models to assess pollutant exposures, doses, and health risks. It does not appear that the use of the analytical data introduces any systematic bias into the analysis (except possibly owing to the lack of speciation data). However, it is likely that both the exposure and toxicologic models provide somewhat conservative estimates of risk. The extent of this conservatism, and of the total uncertainty inherent in the risk estimates, cannot be assessed quantitatively, but it would appear that to claim any greater accuracy for these estimates than plus-or-minus one order of magnitude would not be justified, based on the available information.

6.6 CONSIDERATIONS FOR REMEDIAL ALTERNATIVES

Remedial alternatives for the plant area of the ViChem site should consider that the plant is still operating as of this remedial investigation. However, the future use of the plant is not known.

Back calculations for health-based intake levels of indicator chemicals used at the ViChem site were performed. The following results give the daily oral intake in ug/liter that a 70 kg adult individual consuming two liters of water per day with a 100% absorption rate could be exposed to without experiencing a cancer risk greater than 10^{-6} , or a noncarcinogenic risk greater than a CDI:Rfd ratio of one.

<u>Compound</u>	<u>Acceptable Water Concentration Based on Health Risks</u>
<u>Carcinogens</u>	
Arsenic	0.02 ug/l
Trichloroethene	3.2 ug/l
<u>Noncarcinogens</u>	
Cadmium	17.5 ug/l
Lead	49 ug/l
Mercury	70 ug/l

Back calculations were done to determine acceptable soil concentrations (ASC) of arsenic that would yield a target risk level of 10^{-4} to 10^{-7} for each group of receptors (i.e., residents and workers). Results are shown in Table 6-13. To calculate acceptable soil concentrations, proportions were set up using the observed soil concentrations divided by the calculated risks and setting them equal to the acceptable soil concentrations ($ASC = x$) divided by the target risk levels. The most plausible case concentrations were used. Acceptable arsenic soil concentrations at the 10^{-6} target risk level ranged from 20 mg/kg for on-site workers to 4 mg/kg for lifetime residents. The fivefold increase in the acceptable soil concentration for workers is primarily a result in the reduction of the average number of years exposed. For lifetime residents the average exposure time is 70 years, whereas it is only five years for workers.

Several factors should be considered in conjunction with the back-calculated values.

- o The back-calculated soil arsenic concentrations that correspond to certain risks can be viewed as guidance for establishing a health-based cleanup level for arsenic in the soils. The health-based criteria, along with regulatory guidance and environmental fate and transport predictions, are combined to provide the information for planners to set a cleanup level for arsenic in the soils.
- o Using the residential soil exposure pathway models to set the cleanup level for arsenic on the site soils may be applicable, but must be viewed cautiously. The residential soil models assume that the soil is regularly contacted by a receptor, which would occur in a back yard, for example. In only one instance, the residence adjacent to the former chicken coop area by well EW-14, is a contaminated soil zone directly adjacent to a residence without there being any access restriction between the residence and the contaminated soil zone. The contaminated soils in the lagoon area are fenced to prevent access. The contaminated soils near well cluster EW-15 are not fenced; however, the area is surrounded by woods with the closest house being approximately 400 feet away.
- o Remedial alternatives and cleanup criteria must also consider the future use of the plant. The plant is now active, and as such residential access to most of the contamination soil zones is limited. If the plant were no longer active, then simply preventing residential access to contaminated soil zones would be sufficient

TABLE 6-13

ACCEPTABLE SOIL CONCENTRATIONS FOR
ARSENIC AT VARIOUS TARGET RISK LEVELS

<u>TOTAL CANCER RISK</u>	<u>10×10^{-4}</u>	<u>1×10^{-5}</u>	<u>1×10^{-6}</u>	<u>1×10^{-7}</u>
Residential Exposure Soil Concentration (ppm)	400	40	4	0.4
Worker Exposure Soil Concentration (ppm)	2000	200	20	2

to minimize future health risks via soil exposure. The present data set shows that off-site surface soil migration has not been occurring. However, this may not satisfy regulatory guidance (the NJDEP's 20 mg/kg arsenic in soil department guidance for soil cleanup), and may not satisfy environmental fate and transport predictions (the arsenic in the contaminated soils may leach into the groundwater). Also, preventing access would require continual administrative oversight.

- o If it is assumed that the plant is no longer active in the future, and it is deemed undesirable to simply prevent access, then health-based cleanup criteria should be considered. Under this scenario, it is desirable to know what level to clean the soils to such that the remaining arsenic poses an acceptable health risk to the nearby residents. This would be required since, under these assumptions, access to the site would not be restricted and residents could come into contact with the plant soils in the same fashion they would contact soils in any area away from their house.
- o The residential soil exposure models can be used to approximate the health risks that would remain after cleaning the plant soils to various arsenic soil concentrations, assuming there were no access restrictions. However, recall that the residential models assume that the soil is regularly contacted by the receptor, as would occur in a backyard. Since, under these assumptions, the majority of the contaminated soil areas would not be in a backyard but would instead be an off-site play/hiking area, it is likely that the frequency of exposure to the remediated ViChem plant soils would be less than the frequency of exposure to backyard soils used in the residential soil model. As such, the cleanup levels and risks are probably too conservative. That is, the risks to residents from exposure to plant soils after cleanup would probably be lower than those shown on Table 6-13 at the same remaining arsenic concentration. Said another way, the cleanup level to produce a certain risk is probably higher than shown in Table 6-13. However, it is not possible to quantify how much effect this has on the cleanup levels, since the risk calculations have some uncertainty built into them already as discussed in Section 6.5.

If remedial action is taken at the ViChem plant, the mobility of arsenic in sandy soils should also be considered. Figures 2-8a to 2-8n show the vertical cross sections of arsenic distribution

from soil borings taken when Ebasco wells 1-15 were installed. The majority of wells show low arsenic concentration at depths ranging from 20 to 80 feet. Therefore, any remedial action taken for soil should consider the depth of contamination and the rapid movement of arsenic in the soil (see Section 5.1 for greater detail).

The groundwater at the ViChem site flows into the Maurice River system (Figures 1-2 and 1-3), which runs approximately 32 miles into the Delaware Bay and includes Union Lake, a large, previously used recreation area. Therefore, any decision whether to remediate the groundwater at the ViChem plant site, and if so in what manner, should consider the downstream effects.

6.7 ENVIRONMENTAL ASSESSMENT

The USEPA's Environmental Response Team performed a detailed investigation of the environmental impacts in the Blackwater Branch and the Maurice River downstream from the ViChem site. Their report is included as an appendix in the River Areas RI Report (Ebasco, 1989c).

Pertinent findings of their report may be summarized as follows:

- o There is an adverse impact to the benthic communities in the Blackwater Branch downstream from the ViChem plant site, which takes the form of lower species diversity and a toxic response in bioassay tests done with the sediments; and
- o The impact lessens downstream in the Maurice River, probably resulting from dilution. The Maurice River has a much higher flow rate than the Blackwater Branch.

Potential impacts to terrestrial animals and plants were not considered in detail in the RI/FS. The reasons for this are as follows:

- o Arsenic was either undetected or detected at low concentrations in soils sampled off the plant site, and was also undetected or detected at low concentrations on the plant site in areas where past manufacturing activities did not occur. The highest off-site soil arsenic concentration was 78 ppm. However, this sample was taken fairly close to the soil dumping area (the clearing by well cluster EW-15), where contaminated soils were dumped in the past. When three additional samples were taken further removed from this area in undeveloped woodlands, arsenic was undetected. It is clear from the data that wind-blown arsenic soil contamination is not a significant pathway for migration at the site.

- o Bioaccumulation of arsenic in plants is generally low. A review of environmentally released radionuclides (Baes, et al., 1984) gives arsenic soil to plant concentration factors of 0.040 to 0.006 for vegetative and reproductive portions of plants, respectively. This, combined with the low levels of arsenic found in the residential and off-site areas, yields low levels of arsenic uptake.
- o In terms of animals, the most likely terrestrial animals to be hunted are deer, squirrels, and rabbits. These animals are all mobile, making it difficult to model arsenic ingestion first for the animals, and second for humans consuming the hunted meat. Again, because of the low level of arsenic seen in nonmanufacturing area soils, and because of the low uptake rates in plants these animals would eat, impacts to terrestrial animals were not considered significant.

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7.0 BENCH-SCALE TREATABILITY STUDIES

The bench-scale treatability studies for the arsenic-contaminated soils and groundwater from the ViChem site were conducted to produce adequate data for the evaluation of the technical feasibility and cost-effectiveness of the treatment processes tested. Based on the generally feasible technologies for arsenic treatment in soils, the following bench-scale tests were conducted:

- o Chemical fixation and solidification test; and
- o Chemical extraction of arsenic from soils test.

ViChem has demonstrated the physical-chemical precipitation for arsenic removal from contaminated groundwater. ViChem uses this technique in their existing wastewater treatment plant and can reportedly meet a 0.05 mg/l total arsenic discharge level periodically if the influent concentration is low. If the influent concentration is high, however, the system may not achieve this level. Therefore, the following bench-scale tests were conducted for polishing the treated effluent after it was pre-treated by physical-chemical precipitation to remove most of the arsenic:

- o Adsorption of arsenic;
- o Removal of arsenic by ion exchange; and
- o Removal of arsenic by reverse osmosis.

The fixation tests were conducted by Lopat Enterprises, Inc. and the extraction test and groundwater polishing tests were performed by Hittman Ebasco Associates Incorporated (HEAI) during the summer and fall of 1987.

Each of these bench-scale tests is discussed separately in the following subsections. For each test, the discussion covers the testing objectives, description of the test, the results and the conclusion. The laboratory testing materials (e.g., soils), apparatus, procedures, and results of the bench-scale tests are presented in Appendices G, H and I of this report.

7.1 SOIL FIXATION TEST

Soils from the ViChem site contain total arsenic concentrations in the range of not detected to 400 mg/kg. Four arsenic species contained in the soils are As (V), As (III), monomethyl arsenic acid (MMAA) and dimethyl arsenic acid (DMMA). The inorganic arsenate is estimated to be approximately 75% of the total arsenical species. The laboratory analysis for the chemical fixation of soils is described in Appendix H.

The soil sample for the chemical fixation tests was collected from the "hot spot" area by well cluster EW-14 on August 14, 1987. The sample tested was a composite sample with

individual samples collected from around the area. The area was chosen for sampling based on the preliminary results of the surface soil sampling.

7.1.1 Objectives

The purpose of the fixation test was to confirm whether arsenic in the soil could be chemically stabilized or physically bound to the soil such that leachable arsenic concentrations were less than 5 mg/l after performing the RCRA Extraction Procedure Toxicity Test (EP Tox) on the fixed soil. At the time the tests were performed, it was believed that if the leachate arsenic concentrations were less than 5 mg/l, the fixed soil would then be considered nonhazardous and could be disposed in a nonhazardous waste landfill. Subsequent guidance has been received on the criteria for nonhazardous waste disposal of the treated soils. These criteria are discussed in detail in the plant site FS report (Ebasco, 1989b).

7.1.2 Description of Test

The fixation test consisted of four (4) sequential tasks:

- o Soil characterization;
- o Chemical fixation and solidification with different formulations;
- o Unconfined compressive strength (UCS) test and RCRA Extraction Procedure (EP) Toxicity Test; and
- o USEPA Multiple Extraction Procedure (MEP) test.

Soil Characterization

The soil sample was analyzed for total arsenic content and total organic carbon content to determine whether the sample was representative and suitable for testing. The sample was found to contain total arsenic of 400 mg/kg and total organic carbon of 4,100 mg/kg. This was considered representative of the highest arsenic concentration seen in the soils at the ViChem site.

Fixation and Solidification

Three samples were treated using three different formulations in an attempt to economically transform the soil into materials which would meet the performance criteria (e.g., leachable arsenic concentration below 5 mg/l and 1,500 lb/ft² of UCS).

A commercial silicated blend known as K-20/LSC Lead-in-Soil Control System developed and manufactured by Lopat Enterprises, Inc. of Wanamassa, New Jersey was selected because of its ability to be custom-blended as needed for a particular application. In addition, the K-20/LSC System has been demonstrated and proven to be effective for essentially all of

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the toxic metals (e.g., Pb, Ba, Cd, Cr, As, Hg, etc.). Although to a lesser degree, K-20/LSC has also been proven effective for certain organic compounds such as PCBs.

As shown in Table 7-1, the three samples were chemically fixed and solidified using three different mixtures of chemicals (such as Darco Gro-Safe Activated Carbon), additives (Portland cement Type I, lime and fly ash Type F) and the proprietary reagent (K-20/LSC). The treated samples were allowed 48 hrs of curing and drying.

UCS Test and EP Toxicity Test

The treated samples were tested for unconfined compressive strength (UCS) during the 48-hour curing and the EP Toxicity test (40 CFR 261.24) after 48 hours of curing.

MEP Test

The sample which best complied with the performance criteria was further tested by the USEPA Multiple Extraction Procedure (MEP) test to estimate the long-term stability of exposure to acid rain (47 FR 52686-87, November 22, 1982). If the solidified sample complied with the leachable concentration of 5 mg/l for all ten sequential extractions, a duplicate treated sample would be prepared to demonstrate the reproducibility of the treatment.

7.1.3 Results

As shown in Table 7-1, all three treated samples meet the performance criteria of fixation and solidification (i.e., UCS requirement of 1,500 lb/ft²). The leachable arsenic concentrations resulting from the EP Toxicity tests were in the range of 0.2 to 0.4 mg/l.

Sample 1106-83-01 consisted of soil, K-20/LSC, activated carbon, Portland cement, water and fly ash. After 48 hours of curing, the mixtures passed the RCRA EP Toxicity test and its unconfined compressive strength reached 9,000 lbs/ft² as measured by ASTM unconfined compressive strength test. This strength is higher than the 1500 lb/ft² generally required for landfilling and is sufficient to support truck traffic and other earth moving equipment. The soil mixture volume was increased approximately 17% of the original soil volume due to the addition of cement. Cost for a full scale operation was estimated to be \$150 to \$200 per cubic yard of soil.

Sample 1106-83-02 is similar to Sample 1106-83-01 but lime was also added to the mixture. The mixture passed the EP Toxicity test and had an unconfined compressive strength of 9,000 lbs/ft². There was an approximately 25% increase of the mixture volume after drying and solidification. The cost for a full-scale operation was estimated to be \$175 to \$225 per cubic yard of soil.

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TABLE 7-1

SUMMARY OF TREATABILITY TESTS FOR THE CHEMICAL FIXATION AND SOLIDIFICATION OF ARSENIC IN SOIL

T O T A L A R S E N I C C O N C E N T R A T I O N														
Sample Number	Sample Treatment	USC (lb/ft ²)	Volume Change (%)	EPTox Test (mg/l)	Multiple Extraction Procedure (MEP Tests (mg/l))									
					1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
1. 1106-83-01	400 grams of Sediment +0.5%* K-20 LSC **+ 2% Darco Gro-Safe Activated Carbon + 40% Portland Cement TYPE I + 20% Type F Fly Ash + 26% Water.	9,000	+17	0.24	0.20	0.20	0.21	0.15	0.15	0.17	0.07	0.13	0.17	0.14
				0.27	0.14	0.10	0.12	0.10	0.08	0.07	0.07	0.08	0.11	0.14
2. 1106-83-02	400 grams of Sediment + 0.5% K-20 LSC + 2% Darco Gro-Safe Activated Carbon + 20% Lime + 20% Type I Portland Cement + 15% Type F Fly Ash + 28% water.	9,000	+25	0.36										
3. 1106-84-01	400 grams of Sediment + 0.5% K-20 LSC + 2% Darco Gro-Safe Activated Carbon + 40% Lime + 20% Type F Fly Ash + 34% water.	5,800	+16	0.22										

*Percentage of Sample Weight

**K-20 LSC (K-20 Lead-in-Soil Control System) is a silicate based fixation reagent and a proprietary reagent of Lopat Enterprises, Inc.

Sample 1106-84-01 is similar to Sample 1106-83-02 but Portland cement was not used in the mixture. The mixture passed the EP Toxicity test and had 5,800 lbs/ft² of unconfined compressive strength, above the performance criteria of 1,500 lbs/ft². The mixture volume increased approximately 16% over the soil volume. Costs for full scale operation were estimated to be \$200 to \$250/yd³ of soil.

Sample 1106-83-01 was found to be the most promising of the three test formulations and was therefore selected to undergo MEP testing. The selection was made based on the consideration of cost-effectiveness and the potential for the least volume increase of the three mixtures.

As shown in Table 7-1, the leachable arsenic concentration from the MEP test was in the range of 0.07 to 0.21 mg/l which is far below the toxicity criterion of 5 mg/l. All ten sequential extractions performed as part of the MEP test passed the toxicity criterion.

A duplicate treated sample was then prepared for MEP testing. This duplicate sample also passed the MEP test and demonstrated the reproducibility of the treatment.

The K-20-/LSC System is an inorganic silicate-based material that is nontoxic, nonhazardous, and easy and safe to apply. The major functions of the K-20/LSC System that contribute to the successful fixation and solidification of arsenic compounds are the:

- o Precipitation of heavy metals contaminants;
- o Encapsulation of heavy metals contaminants; and
- o Protection and stabilization of encapsulated metal contaminants from acid rain.

7.1.4 Conclusions

Based on these laboratory results, it is concluded that the arsenic compounds in ViChem plant site soils can be chemically stabilized by fixation such that the arsenic is very slightly leachable. As discussed in detail in the Plant Site FS, this is a promising technology for treating the plant soils for nonhazardous disposal.

7.2 ARSENIC EXTRACTION FROM SOIL TEST

The soil sample for the arsenic extraction tests was collect adjacent to the on-site unlined lagoon UL-A on July 17, 198. The sample tested was a composite sample with samples obtain from many spots in the area. The laboratory analysis for t. chemical extraction of soils is described in Appendix G.

7.2.1 Objectives

The primary purpose of the chemical extraction tests was to obtain performance data on the extraction of arsenic oxides and methylated arsenic oxides from the soils. The performance criterion required that the treated soil contain a total arsenic concentration below 20 mg/kg, the NJDEP's department guidance for arsenic cleanup levels in soils, cited in the New Jersey Environmental Cleanup Responsibility Act Standards (ECRA, N.J.A.C. 7:26B-1.1 et. seq.). At the time of the test it was believed that if successful, the treated soil would be considered nonhazardous and could be disposed of in a nonhazardous waste landfill. Subsequent guidance on the criteria for nonhazardous disposal has been received and is discussed in detail in the Plant Site FS Report (Ebasco, 1989b).

In addition, the results of this test provided the data to determine the amount of and costs for chemicals required for successful extraction. This information was needed to determine the economic feasibility of extracting arsenic from the soils.

7.2.2 Description of Test

The chemical extraction tests consisted of three sequential tasks:

- o Soil characterization;
- o Comparison of extraction reagents; and
- o Evaluation of pH effects on arsenic removal.

Since the temperature effects on the extraction of arsenic from sediment (see River Areas and Union Lake RI Reports - Ebasco, 1989, c and e) revealed that high temperature did not result in any improvement in arsenic extraction, the evaluation of temperature effects was not tested on the plant soils.

Soil Characterization

The soil sample was analyzed for total arsenic content and total organic carbon content to determine whether the sample was suitable for testing. The sample contained a total arsenic concentration of 114 mg/kg and a total organic carbon concentration of 5,730 mg/kg. The sample represented a more average concentration of arsenic in the ViChem site soils.

Comparison of Extraction Reagents

The sample was extracted with water, with and without added chelating compounds. Sodium citrate, sodium oxalate, and ethylenediaminetetra-acetate (EDTA), all commonly used extracting agents, were the three chelating reagents tested. A 200 g

sample was added with 200 ml of aqueous reagent to form a slurry. The slurry was stirred continuously for two hours at a speed of 40 rpm. The treated samples were allowed to settle and the settled samples were then analyzed for total arsenic and total organic carbon. The tests for the chelating reagents evaluation were conducted at room temperature and a pH of 7.0.

Evaluation of pH Effects on Arsenic Removal

The samples were extracted with water at different pH levels to determine the optimal pH for arsenic extraction. Sodium hydroxide and hydrochloric acid were used to adjust the samples from near-neutral condition to acid and alkali conditions. The samples were extracted with water at pHs of 7.0, 12.0 and 3.0.

7.2.3 Results

As shown in Table 7-2, the extraction without a chelating reagent did remove arsenic from the soils to 17 mg/kg which is below the performance criteria (i.e., 20 mg/kg of total arsenic) at room temperature and near-neutral pH. Chelated extraction with sodium citrate was less effective than water at removing arsenic under these conditions. The extracted sludge after washing (to remove residual reagent) contained 44 mg/kg of total arsenic, higher than the target concentration of 20 mg/kg of total arsenic.

Chelated extraction with sodium oxalate and EDTA were similar to sodium citrate and did not remove the arsenic from the soil below the performance criterion.

The pH effects on the removal of arsenic from the soils were poor. Adverse effects resulted in the extreme acidic condition (pH of 3.0), since the final concentration was greater than that achieved by water alone. The experiment indicated that the extreme alkali condition (pH of 12.0) did not result in any improvement of arsenic extraction with water only as shown in Table 7-2.

Costs for a full-scale operation of arsenic extraction from the ViChem site soils were estimated to be \$100 to \$150/yd³ using water only.

7.2.4 Conclusions

Based on these laboratory results, it is concluded that the target arsenic concentration (below 20 mg/kg of total arsenic) can be achieved for the soils by water extraction at a neutral condition and at room temperature (24°C). It should be noted that since the soil chemical constituents and physical structures dominate the extraction behaviors, a pilot-scale test is deemed necessary to confirm this water extraction result. Also, as stated previously, the target criteria for nonhazardous disposal of treated soils has changed from that anticipated at the beginning of the study. The current criteria are discussed in detail in the Plant Site FS Report (Ebasco, 1989b).

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TABLE 7-2

SUMMARY OF TREATABILITY TESTS FOR THE EXTRACTION OF
ARSENIC FROM SOIL

Soil Characterization

<u>Sample Number</u>	<u>Untreated Soil</u>	
	<u>Total As</u> <u>(mg/kg)</u>	<u>TOC</u> <u>(mg/kg)</u>
836-003-01	114	5,730

Selection of Chelating Reagents

<u>Sample Number</u>	<u>Total As (mg/kg)</u>	<u>Treated Soil*</u>	
		<u>Total As</u> <u>(mg/kg)</u>	<u>TOC</u> <u>(mg/kg)</u>
836-006-05	No Chelator, pH = 7.0, 24°C	17	82
836-009-05		41	
836-006-01	Sodium Citrate 2,575 mg/l, pH = 7.0, 24°C	43	90
836-006-03		40	
836-006-02	Sodium Oxalate 2,835 mg/l, pH = 7.0, 24°C	44	97
836-006-03		35	
	EDTA (Tetrasodium Salt) 1,173 mg/l, pH = 7.0, 24°C		81

pH Effects

<u>Sample Number</u>	<u>Total As (mg/kg)</u>	<u>Treated Soil</u>	
		<u>Total As</u> <u>(mg/kg)</u>	<u>TOC</u> <u>(mg/kg)</u>
836-006-05	No Chelator, pH = 7.0, 24°C	17	82
836-006-04		17	84
836-006-06	No Chelator, pH = 3.0 24°C	38	98

* Performance criterion - Treated sediments contain total As less than 20 mg/Kg.

7.3 ADSORPTION OF ARSENIC FROM GROUNDWATER TEST

The groundwater sample for the arsenic adsorption tests was collected from ViChem's monitoring well MW-1 on July 29, 1987. MW-1 is located near the lined concrete lagoon, LL-2. The laboratory analysis for groundwater is described in Appendix I.

7.3.1 Objectives

The primary purpose of the arsenic adsorption tests was to obtain performance data on the adsorption of arsenic oxides and methylated arsenic from the groundwater pretreated by physical-chemical precipitation to assess the feasibility of further polishing by the activated adsorption technology. The performance data would be the basis for evaluating the technical feasibility and cost-effectiveness of the activated adsorption processes in terms of producing a final effluent with total arsenic concentration below 0.05 mg/l, the Federal Safe Drinking Water Standard. If successful, the treated water would comply with the New Jersey State Pollution Discharge Elimination System (SPDES) permit requirements and could be discharged to the nearby receiving water body.

7.3.2 Description of Test

The arsenic adsorption test consisted of three steps:

- o Groundwater characterization;
- o Activated alumina adsorption; and
- o Titanic oxide adsorption.

Granular activated carbon (GAC) adsorption studies published in the literature indicated that the GAC treatment technology was not effective for arsenic removal from aqueous wastes (Lee and Rosehart, 1972). Therefore metal oxide adsorbents were tested instead of GAC adsorbents.

Groundwater Characterization

The groundwater sample from MW-1 was analyzed for total arsenic content to determine whether the sample was suitable for testing. The sample was found to contain total arsenic of 1.61 mg/l which may be within the range of total arsenic concentration in the ViChem treated effluent. The ViChem wastewater treatment plant consists of a series of unit operations including acidification, potassium permanganate oxidation, ferric chloride precipitation, solids/liquids separation and effluent pH adjustment with sodium hydroxide. The plant does not always achieve an arsenic content in the effluent of 0.05 mg/l, therefore these polishing technologies were investigated.

Activated Alumina Adsorption Isotherm Tests

The batch adsorption tests consisted of a series of tests in which six difference dosages of adsorbent (activated alumina) were mixed with the sample on a shaker table lasting for five days. A series of six alumina absorbent dosages, 5.1 mg/l, 11.0 mg/l, 22.1 mg/l, 43 mg/l, 82.1 mg/l and 103 mg/l were tested for five days. Activated aluminum oxides (F-1 grade ALCOA, 28-48 mesh) were tested at a pH of 6.0 and a room temperature. A pH of 6.0 was indicated to be an optimum value for both As (V) and As (III) adsorption onto alumina by previous experiments in the referenced literature.

The testing procedures included recording the dry weight of adsorbents, mixing adsorbent and sample water on shaker tables, separating adsorbent particles from the liquid, and analyzing the total built-up arsenic content of the decantant. The liquid phase of the shaken samples was decanted and filtered and analyzed for total arsenic.

Titanic Oxide Adsorption Isotherm Tests

Reagent grade titanic oxide (TiO) from the Fisher Chemical Company (T-315), without any further purification or pretreatment, was used for adsorption isotherm tests in procedures similar to the alumina adsorption tests. A series of six titanic adsorbent dosages, 10.0 mg/l, 20.0 mg/l, 40 mg/l, 80.0 mg/l, 160 mg/l and 400 mg/l, were tested for the five day shaker adsorption process.

7.3.3 Results

The alumina adsorption testing results at various adsorbent dosages are presented in Table 7-3, and a plot of $\log (X/M)$ versus $\log C$ are presented in Figure 7-1. X/M is the amount of arsenic adsorbed per unit weight of adsorbent, and C is the equilibrium concentration of arsenic remaining in solution. As shown in Figure 7-1, the best fit to calculate the empirical constants in the Freundlich adsorption isotherm equation is

$$X/M = 0.117 C \exp 0.46$$

where C is in ug/l
 X/M is in mg/g

This equation can be used to estimate the alumina adsorption capacity and efficiency. As shown in Table 7-3, the alumina dosages of 43.0 mg, 82.1 mg and 103 mg in Experiment #1, and alumina dosages of 50 mg, 100 mg and 500 mg in Experiment #2 removed arsenic from the groundwater to concentrations below the performance criteria of 0.05 mg/l. It is estimated that for an effective equilibrium arsenic concentration of 50 ug/l, absorbent loading capacity would be approximately 0.71 mg arsenic per gram of alumina. In order to reduce the initial arsenic concentration

TABLE 7-3

ALUMINA ADSORPTION DATA SUMMARY

FLASK	M (mg)	C (ug/L)	X (ug)	X/M (mg/g)
-------	--------	----------	--------	------------

EXPERIMENT #1

A	0	188	-----	-----
B	5.1	178	2.5	0.49
C	11.0	143	11.25	1.02
D	22.1	101	21.75	0.98
E	43.0	52	34.00	0.79
F	82.1	33	38.75	0.47
G	103	36	38.00	0.37

EXPERIMENT #2

A	0	191	-----	-----
B	20	98	23.25	1.16
C	50	50	35.25	0.70
D	100	15	44.00	0.44
E	500	11	45.00	0.09

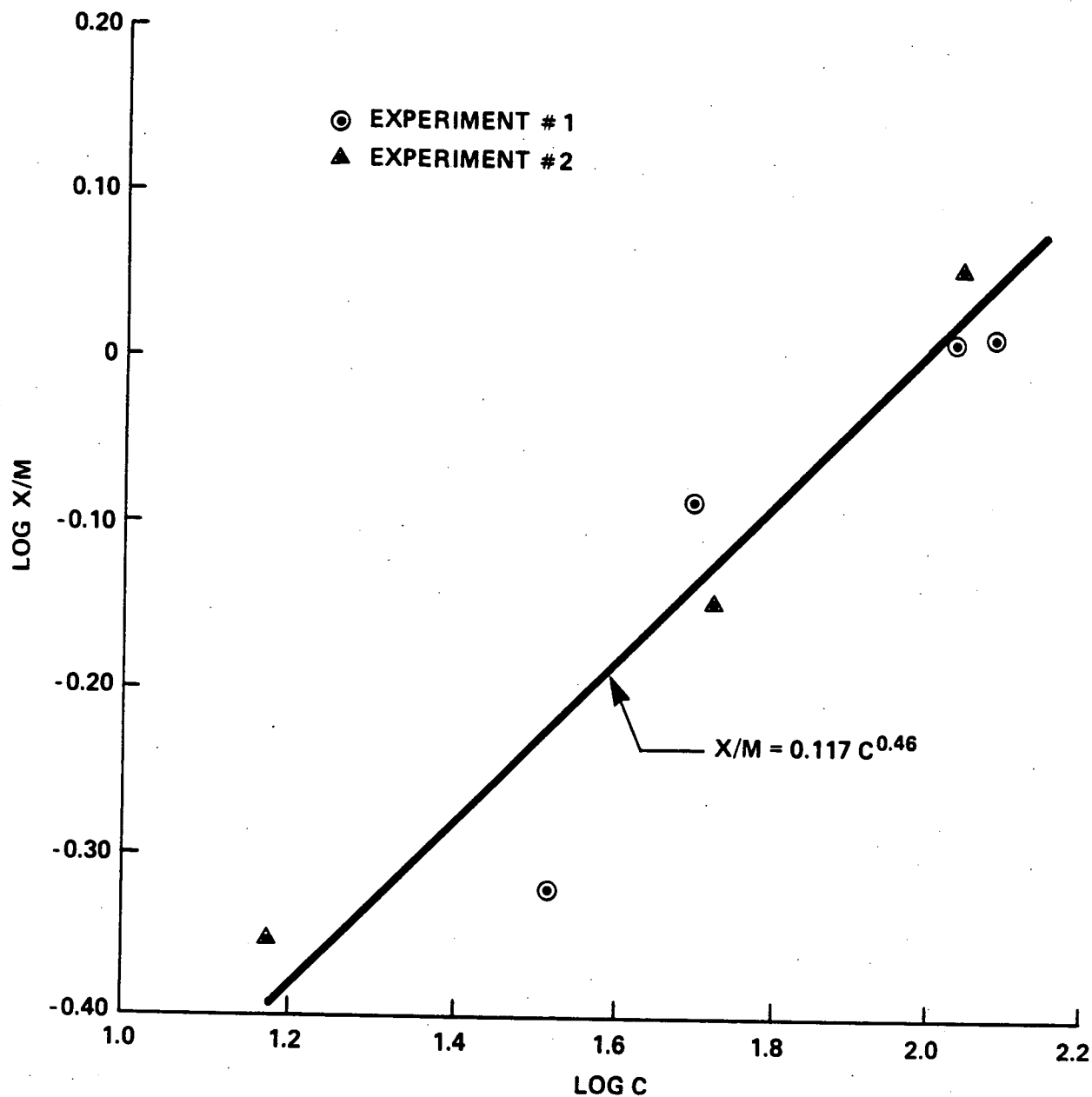
M = Adsorbent added to flask

C = Aqueous As concentration after 5 days

X = Total As removed from solution by adsorbent

X/M = Solid phase loading capacity

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FIGURE 7-1 PLOT OF ALUMINA ADSORPTION ISOTHERM EQUATION
EBASCO SERVICES INCORPORATED

JIN 001 1206

from 1,610 ug/l to the 50 ug/l target value, approximately 2.3 grams of alumina would have to be added to each liter of ViChem groundwater, i.e., 2300 mg/l alumina dosage rate.

It should be noted that in the results shown in Table 7-3, the initial concentration of arsenic was reduced approximately 88% (from 1,610 ug/l to 188 ug/l) after five days shaking and mixing. The potential mechanisms of this phenomenon would be:

- Vigorous aeration oxidized most of the dissolved arsenic to form fine arsenic oxide particles which were filtered prior to the total arsenic analysis; and
- Adherence of fine arsenic oxide particles to the borosilicate glass walls.

In order to determine the exact reason, a duplicated test using teflon flasks was performed. The testing results (Experiment #2) are presented in Table 7-3. As shown in Table 7-3, it was determined that arsenic oxidation is the primary function of the initial arsenic concentration reduction.

The titanic oxide adsorption test results at various adsorbent dosages are presented in Table 7-4. The titanium oxides were unsuitable for removing arsenic from the groundwater. As shown in Table 7-4, adding this adsorbent actually increased the arsenic concentration in the treated groundwater. The laboratory grade TiO contained approximately 2.4 mg/l arsenic according to the Fisher Chemical Company. In consideration of the observed leaching of arsenic from the adsorbent, isotherm constants were not calculated for the TiO experiment.

Costs for full-scale operation of activated alumina adsorption were estimated to be \$0.25 to \$0.35 per 1,000 gallons of the pretreated groundwater excluding the cost of spent alumina disposal.

7.3.4 Conclusions

Based on these laboratory results, it was concluded that the activated alumina adsorption could be used to polish the ViChem groundwater pretreated by physical-chemical precipitation to produce a final effluent containing a total arsenic concentration below 0.05 mg/l, the Federal Safe Drinking Water Standard. In general, the alumina adsorption capacity is in the range of 2 to 3 mg of arsenic per gram of alumina (Lee and Rosehart, 1972). The ViChem groundwater polishing tests show a much lower adsorption capacity of ALCOA F-1 alumina, although the adsorbent loading capacity is directly proportional to the concentration, especially for the low concentration of arsenic in the groundwater tested. ALCOA suggested that the F-1 alumina adsorbent be conditioned by hydrochloric acid to remove impurities. This would significantly increase the effective arsenic loading capacity.

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TABLE 7-4

TITANIUM OXIDE ADSORPTION DATA SUMMARY

FLASK	M (mg)	C (ug/L)	X (ug)	X/M (mg/g)
A	0	65	-----	-----
B	10.0	97	-8.0	-0.80
C	20.0	148	-20.75	-1.04
D	40.0	196	-32.75	-0.82
E	80.0	160	-23.75	-0.30
F	160	256	-47.75	-0.30
G	400	266	-50.25	-0.13

M = Adsorbent added to flask

C = Aqueous As concentration after 5 days

X = Total As removed from solution by adsorbent

X/M = Solid phase loading capacity

7.4 ION EXCHANGE REMOVAL OF ARSENIC FROM GROUNDWATER TEST

The groundwater sample for the ion exchange tests was collected from the ViChem's monitoring well MW-1 on July 29, 1987. MW-1 is located near the eastern lined lagoon, LL-2.

7.4.1 Objectives

The primary purpose of the arsenic ion exchange tests was to obtain performance data on the ion exchange of arsenic from the groundwater pretreated by physical-chemical precipitation to assess the feasibility of further polishing by the ion exchange technology. The performance data such as ion exchange capacity, breakthrough characteristics and regeneration requirements would be the basis for evaluating the technical feasibility and cost-effectiveness of the ion exchange process in terms of producing a final effluent with a total arsenic concentration below 0.05 mg/l, the Federal Safe Drinking Water Standards. If successful, the treated water would comply with the New Jersey State Pollution Discharge Elimination System (SPDES) permit requirements and could be discharged to a nearby receiving water body.

7.4.2 Description of Test

The arsenic ion-exchange tests consisted of four steps:

- o Groundwater characterization;
- o First run column ion exchange elution test;
- o Resin regeneration; and
- o Second run column ion exchange elution test.

Two types of commercially available resins were selected for the entire cycle of ion exchange test and included:

- o Dowex AG 1-X8 resin, a strong base anion exchange resin in chloride form and 100-200 mesh size; and
- o Amberlite IRA-400 resin, a strong base anion exchange resin in chloride form and 50-100 mesh size.

Groundwater Characterization

The groundwater sample was analyzed for total arsenic content to determine whether the sample was suitable for testing. The sample was found to contain total arsenic of 0.4 mg/l which is within the range of the total arsenic concentration believed to be present periodically in the effluent from the ViChem wastewater treatment plant.

Dowex AG1-X8 Resin Ion Exchange Column Tests

The minicolumn ion exchange tests were performed under the following experimental conditions:

Average Flow Rate = 2.3 ml/min
Bed Volume (void) = 6.6 ml
Empty Bed Contact Time (EBCT) = 2.8 min
Effluent Samples = 6
Run Time = 1,440 min (24 hrs)

The groundwater sample was pH adjusted at 9.2 with sodium hydroxide, the optimal pH for this type of resin ion exchange. Table 7-5 presents the results of the ion exchange tests.

Upon the completion of the first 24-hour elution run, the resin was regenerated using a 10% (w/v) sodium chloride solution. The resin bed was allowed to soak for 24 hrs in a 140 ml NaCl solution. The bulk regenerant contained approximately 8,860 mg/l total arsenic, meaning the regenerant recovered approximately 95% of the arsenic removed.

The second run ion exchange column tests were performed by the same procedure as first tests and under the following experimental conditions:

Average Flow Rate = 1.9 mg/min
Bed Volume (void) = 6.6 ml
Empty Bed Contact Time = 3.5 min
Effluent Samplings = 6
Run Time = 1,770 min (29.5 hrs)
pH = 9.2

Table 7-5 also presents the results of the second run ion exchange tests.

Amberlite IRA-400 Resin Ion Exchange Column Tests

The Amberlite IRA-400 resin was used for the ion exchange column tests in procedures similar to the Dowex AG1-X8 resin tests. The ion exchange tests consisted of a first run 24-hour elution, resin regeneration, and a second run 24-hour elution under the following experimental conditions:

1st Elution Run:

Average Flow Rate = 2.8 ml/min
Bed Volume (Void) = 7.4 ml
Empty Bed Contact Time = 2.7 min
Effluent Samplings = 7
Run Time = 1440 min (24 hrs)

TABLE 7-5

ANALYTICAL SUMMARY OF DOWEX AG 1-X8 ION EXCHANGE TEST

RUN #1 TO: 9/16/87 @ 1645 (Initial Time)

<u>Sample Identification</u>	<u>Time of Collection</u>	<u>Arsenic Content (ug/L)</u>
836-013-01	To + 7 min.	< 5
836-013-02	To + 1 hr.	< 5
836-013-03	To + 4 hrs.	< 5
836-013-04	To + 8 hrs.	< 5
836-013-05	To + 15.75 hrs.	6
836-013-06	To + 24 hrs.	10

Total Arsenic Content of Bulk Refrigerant: 8,860 ug/L
 Total Volume = 140 ml

RUN #2 To: 9/21/87 @ 1530 (Initial Time)

<u>Sample Identification</u>	<u>Time of Collection</u>	<u>Arsenic Content (ug/L)</u>
836-016-01	To + 7 min.	38
836-016-02	To + 1 hr.	13
836-016-04	To + 8 hrs.	13
836-016-05	To + 17.5 hrs.	8
836-016-06	To + 24 hrs.	10
836-016-03	To + 29.5 hrs.	10

Resin Regeneration:

Regenerant = 10% (W/V) sodium chloride

Regenerant and Rinse Volume = 145 ml

Arsenic content of Bulk Regenerant = 3,420 ug/l (65% of arsenic recovered)

2nd Elution Run:

Duplicated 1st Elution Run

Table 7-6 presents the arsenic concentration of each aliquot of column elutriate collected at each sampling interval during each run.

7.4.3 Results

As shown in Table 7-5, AG1-X8 resin proved to be a very effective resin for removing dissolved arsenic from the ViChem groundwater at a pH of 9.2. Throughout most of the study, the arsenic concentration of the column elutriates were at or just slightly above instrument detection limit (5 ug/l). In every case, the arsenic concentrations were well below the 50 ug/l target level. Based on the experimental results, the AG1-X8 resin can produce more than 500 times the bed volume of dischargeable water continuously for over 24 hours. In addition, regeneration utilizing approximately 20 times the bed volume with a 10% sodium chloride solution can recover approximately 95% of the removed arsenic. This figure agrees with the typical regeneration efficiencies for ion-exchange resins.

As shown in Table 7-6, Amberlite IRA-400 has a lower ion exchange capacity, a shorter breakthrough time and poor regeneration efficiency compared with the Dowex AG-1-X8 resin. The average arsenic removal capacity of IRA-400 resin is approximately 94% of the feedstock (98% for AG1-X8). The regeneration recovery efficiency is only 65% for IRA-400 (95% for AG1-X8). Although the Amberlite IRA-400 can remove arsenic from the ViChem groundwater to below the 50 ug/l target level, its operating conditions are less preferred than Dowex AG1-X8.

It should be noted that the arsenic concentrations (35 ug/l to 65 ug/l) seen after the regeneration of the resin are greater than the first run arsenic concentrations (7 ug/l to 33 ug/l). These slight reductions of ion exchange efficiency are due to the difficulty in removing the regeneration waste from the small test tubes, which will not take place in a full-scale operation.

Costs for a full-scale operation of strong base anion resin ion exchange were estimated to be \$0.35 to \$0.50 per 1,000 gals of the ViChem pretreated groundwater, excluding the cost of the regenerant disposal.

TABLE 7-6

ANALYTICAL SUMMARY OF AMBERLITE ION EXCHANGE TEST

RUN #1 TO: September 3, 1987 @ 1530

<u>Sample Identification</u>	<u>Time of Collection</u>	<u>Arsenic Content (ug/L)</u>
836-011-01	To + 7 min.	11
836-011-02	To + 1 hr.	7
836-011-03	To + 4 hrs.	7
836-011-04	To + 8 hrs.	12
836-011-05	To + 16.75 hrs.	33
836-011-06	To + 24 hrs.	27

Total Arsenic Content of Bulk Refrigerant: 3,420 ug/L
 Total Volume = 144 ml

RUN #2 TO: September 9, 1987 @ 1445

<u>Sample Identification</u>	<u>Time of Collection</u>	<u>Arsenic Content (ug/L)</u>
836-012-02	To + 7 min.	65
836-012-03	To + 1 hr.	35
836-012-04	To + 8 hrs.	25
836-012-05	To + 17.5 hrs.	39
836-012-06	To + 16.75 hrs.	19
836-012-07	To + 24 hrs.	23

7.4.4 Conclusions

Based on the laboratory results, it is concluded that the ion exchange process using a strong base anion resin can be used to polish the pretreated ViChem groundwater, producing a final effluent with a total arsenic concentration below 0.05 mg/l, the Federal Safe Drinking Water Standard. The study identified the resin (Dowex AG1-X8) which achieved the 0.05 mg/l total arsenic discharge requirements and produced the performance data of ion exchange for technical and economic evaluation.

7.5 REVERSE OSMOSIS REMOVAL OF ARSENIC FROM GROUNDWATER TEST

The groundwater sample for the reverse osmosis (RO) filtration tests was collected from the ViChem's monitoring well MW-1 on July 29, 1987. MW-1 is located near the eastern lined lagoon LL-2.

7.5.1 Objectives

The primary purpose of the arsenic RO filtration tests was to obtain performance data on the RO filtration of arsenic contaminants from the groundwater pretreated with physical-chemical precipitation to assess the feasibility of further polishing by the reverse osmosis technology. The performance data such as type of membrane, operating pressure, effluent and reject characteristics would be the basis for evaluating the technical feasibility and cost-effectiveness of the RO process in terms of producing a final effluent with total arsenic concentration below 0.05 mg/l, the Federal Safe Drinking Water Standard. If successful, the treated water would comply with the New Jersey State Pollution Discharge Elimination System (SPDES) permit requirements and could be discharged to a nearby receiving water body.

7.5.2 Description of Test

The arsenic RO filtration tests consisted of three steps:

- o Groundwater characterization;
- o First RO membrane filtration test; and
- o Second RO membrane filtration test.

Two types of commercially available RO membranes were selected for polishing the pretreated groundwater containing low arsenic compounds:

- o Spiral wound polyamide membrane; and
- o Spiral wound cellulose acetate membrane.

The Osmonics' products, 192 HR (PA-MSO2) polyamide type membrane and 192 HR (ST-10) cellulose acetate type membrane were used for the reverse osmosis experiment. Both membranes have been utilized extensively for water purification and desalting.

Groundwater Characteristics

The groundwater sample was analyzed for total arsenic and other chemical parameters. The sample was prefiltrated to avoid membrane fouling and plugging. The prefiltrated sample contained:

Total Arsenic = 0.087 mg/l
Total Suspended Solids = 1 mg/l
Alkalinity = 52 mg/l
Sulfate = 61 mg/l
Chloride = 58 mg/l

The arsenic concentration was lower than that used in the other tests although it was obtained from the same well (MW-1). This well had the highest arsenic concentration of the six wells sampled during the site reconnaissance, which were the only results available at the time the treatability samples were obtained. The low arsenic concentration may still be within the range of the treated effluent after physical-chemical precipitation.

Spiral Wound Polyamide Membrane Reverse Osmosis Tests

The laboratory-scale RO system consisted of the membrane, a membrane support structure, a containing vessel and a high pressure pump. Other instruments included osmotic pressure gauges, flow meters, temperature control and glass fiber prefilters. The membrane was tested at three different operating pressures, 400 psi, 500 psi, and 700 psi. All operating conditions were recorded, and both permeate and rejection stream samples were collected and analyzed for arsenic contents. Table 7-7 presents the results of reverse osmosis filtration tests.

Spiral Wound Cellulose Acetate Membrane Reverse Osmosis Tests

The cellulose acetate membrane was tested using the same procedures as the polyamide membrane tests. The test results are also presented in Table 7-7.

7.5.3 Results

The rejection stream of reverse osmosis filtration represents the solute (impurities) built up on the high-pressure side of the membrane while the relatively purified water is transported through the membrane. The volume of the reject generated by RO is about 10 to 25% of the feed volume when an RO system is cost effective. Provisions must be made to treat this potentially hazardous reject stream.

TABLE 7-7

RESULTS AND OPERATING PARAMETERS OF REVERSE OSMOSIS EXPERIMENTSA. SPIRAL WOUND POLYAMIDE MEMBRANE

<u>Operating Pressure (PSI)</u>	<u>Concentrate Flow (gph)</u>	<u>Permeate Flow (gph)</u>	<u>Rejection (%)</u>	<u>Arsenic Content of Permeate (mg/l)</u>
400	230	33	85	<0.005
500	84	38	55	<0.005
700	102*	54	47	<0.005

*Arsenic content of concentrate stream = 0.054 mg/l

A. SPIRAL WOUND CELLULOSE ACETATE MEMBRANE

<u>Operating Pressure (PSI)</u>	<u>Concentrate Flow (gph)</u>	<u>Permeate Flow (gph)</u>	<u>Rejection (%)</u>	<u>Arsenic Content of Permeate (mg/l)</u>
400	250	8.7	96	<0.005
500	84	10	88	<0.005
700	120*	15	87	<0.005

*Arsenic content of concentrate stream = 0.054 mg/l

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As shown in Table 7-7, both spiral wound polyamide and cellulose acetate membranes were technically feasible technologies for removing dissolved arsenic compounds from the ViChem groundwater. Under all operating pressures (400, 500 and 700 psi), the arsenic concentrations of the permeates were below the instrument detection limit (5 ug/l) and were well below the 50 ug/l target level. However, both membranes produced extremely high rejection volumes in the range of 45 to 95%. The increase of operating pressure (400 psi to 700 psi) would not reduce the rejection stream to a normal reverse osmosis operating condition (10 to 25% rejection flow), particularly for the cellulose acetate membrane (96% reduced to 87%).

In general, reverse osmosis is used to reduce the concentrations of dissolved solids, both organic and inorganic. The operating pressure is usually in the range of 400 to 500 psi. The volume of the reject stream generated by reverse osmosis is about 10 to 25%. Provisions must be made to treat this potentially hazardous waste.

Cost of the full-scale operation of a reverse osmosis filtration were estimated to be \$3.50 to \$7.00 per 1,000 gal of the ViChem pretreated groundwater depending upon the requirements of the rejection stream disposal.

7.5.4 Conclusions

Based on these laboratory results, it was concluded that the reverse osmosis processes could be used to polish the ViChem pretreated groundwater and could produce a final effluent with a total arsenic concentration below 0.05 mg/l, the Safe Drinking Water Standard. However, reverse osmosis would not be a cost-effective technology to polish the pretreated groundwater due to generating an extremely high volume reject stream, and the requirements of operating at very high operating pressures.

In the treatment of a hazardous waste contaminated stream, economical use of reverse osmosis would be primarily limited to polishing a low flow stream containing a high concentration of contaminants. The ViChem pretreated groundwater would be a high flow stream containing low arsenic concentrations. Therefore this method is not preferred for use at the ViChem site.

SECTION 8.0

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8.0 SUMMARY AND CONCLUSIONS

This section summarizes the major findings of the RI, and provides recommendations for future work. Potential remedial action objectives are also identified.

8.1 SUMMARY

8.1.1 Nature and Extent of Contamination

The groundwater underneath the site was contaminated with substantial quantities of arsenic. The contamination was restricted to the upper aquifer, identified as the upper sand. The upper sand was approximately 40 to 50 feet thick where contamination was observed. At the base of the upper sand was a geologic unit containing clay laminae, identified as the banded zone. Below the banded zone, arsenic was detected but not above the 50 ug/l MCL. Many samples contained no detectable arsenic.

In addition to arsenic, cadmium contamination was also observed in the groundwater in the upper sand. Cadmium was previously used by ViChem to produce the herbicide ViCad. The cadmium plume was in the same general location as the arsenic plume. Although cadmium was found in the groundwater, it was not found in the soils. TCE and lead were also found in the groundwater. The TCE probably resulted from processes at the plant, while the lead was suspected to occur naturally. Pesticides were detected in monitoring wells at all depths. The pesticides found, however, were not believed attributable to ViChem.

Some of the soils were contaminated with substantial quantities of arsenic. Soils above the water table showed elevated arsenic concentrations in the lagoon area, along the plant road, in the former chicken coop area in the southwest portion of the site, and in the clearing in the southeast corner of the site where soils stripped from the manufacturing area were dumped. The soil contamination was fairly localized. Many of the soil samples showed low or undetectable arsenic concentrations. Some mercury was also found in the soils.

The soils below the water table showed fairly low levels of arsenic, except for the soils at the upper boundary of the banded zone. Elevated arsenic concentrations were seen at that depth in most of the well borings that also displayed elevated arsenic concentrations in the groundwater. Well cluster EW-7 was the only location showing fairly uniform elevated arsenic concentrations with depth to the top of the banded zone. The arsenic concentrations in the soils below the banded zone were low to undetectable.

The soils below Building #9 were also contaminated with arsenic in very high concentrations. Building #9 is a process building where crystalline arsenic wastes were reportedly observed on the

ground in the past. The floor of the building is now covered with concrete and brick and the area around the building is paved; therefore, this arsenic should be fairly protected and immobile unless intersected by a fluctuating water table.

The dust samples taken from the chicken coops displayed substantial quantities of arsenic, cadmium, lead, mercury, and zinc. All of these metals, except possibly zinc, were used in the past for manufacturing herbicides.

Samples of the sediments below the unlined lagoon that currently receives treated water discharge showed elevated arsenic concentrations; however, the arsenic content of the water was low. What was being discharged into the lagoon at the time of sampling was not known. The water in the lined lagoons contained elevated arsenic concentrations.

Both the sediments and the surface water in the Blackwater Branch had elevated arsenic concentrations downstream of the plant, while upstream the arsenic concentrations were very low to undetected.

8.1.2 Contaminant Fate and Transport

The groundwater in the upper sand had a prevailing hydraulic gradient towards the Blackwater Branch to the north and west. There was an upward hydraulic gradient between the upper sand and the Blackwater Branch on both sides of this stream. Physically, this indicated that groundwater should recharge this stream and not flow underneath it.

The arsenic plume in the groundwater extended to the north and west of the plant. The upper sand aquifer was contaminated throughout its thickness, with the highest concentration observed at its base northwest of the plant. No contamination was seen in well cluster EW-1, across the Blackwater Branch from the plant. This was interpreted to indicate that the contaminated groundwater discharges into the Branch and does not migrate below it.

The arsenic flow from the site in the groundwater was estimated based on the groundwater flow and the arsenic concentration in the groundwater. This yielded an estimate of between 2 and 11 metric tons per year of arsenic flowing off the site in the groundwater. The arsenic load in the Blackwater Branch downstream of the site was estimated to be between six and eight metric tons per year based on the flow and arsenic concentration in this stream. This estimate was based on data obtained in 1987, and it compared well with an estimate prepared in 1982.

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These data suggest that the contaminated groundwater flowing from the site was the main source of contamination to the Blackwater Branch. It was estimated that approximately six metric tons of arsenic per year was flowing off-site into the local surface water system where it could be transported downstream.

The present-day arsenic input into the groundwater was estimated to be approximately 0.04 to 0.14 metric tons per year, substantially less than the calculated outflow. This indicated that the effects of past contamination were probably still being observed in the groundwater, with contaminated aquifer materials slowly leaching arsenic into the groundwater.

Based on the low partition coefficients calculated for arsenic on the site soils, it was estimated that it will take many years for the arsenic concentration in the groundwater to fall below 50 ug/l. The estimated times calculated from the groundwater model prepared for the FS depended on the Kd and will be discussed in detail in the FS for the No Action Alternative.

8.1.3 Risk Assessment

The risk assessment considered present day risks to workers from the plant soils and to residents from the residential soils. Future risks were also calculated in the event that contaminated groundwater, which is not presently used as a drinking water source, was used in the future and had the same contamination characteristics that it has presently.

For residents, staged-adult exposure models were developed. This allowed a risk characterization assuming that a resident lived in the vicinity of the plant site for 70 years and took into account the different behavior patterns and body weights which would be manifest over a 70-year lifetime. For workers, exposure to the plant soils was considered for 5 and 20 year durations.

Both worst case and most plausible risk estimates were developed. Worst case risk estimates used worst case exposure assumptions and maximum contaminant concentrations in the soil and groundwater. The most plausible risk estimates used more realistic exposure assumptions and the geometric mean contaminant concentrations in the soil and groundwater. This provided a range of risk estimates for planners and other personnel to use when deciding on the need for health based remedial actions at the site.

For workers, arsenic was the main contaminant of concern in the site soils. The worst case and most plausible risks to workers from exposure to arsenic in the plant soils were 4×10^{-3} and 2×10^{-7} , respectively. Risks to workers from other chemicals detected in the soils were insignificant. Risks to workers from groundwater, even if they consumed the plant production well groundwater, were insignificant since the production well's arsenic concentration was far below the MCL for arsenic, 50 ug/l.

For residents, arsenic was again the main contaminant of concern. The worst-case and most plausible risks to residents from exposure to arsenic in the residential soils were 1×10^{-4} and 6×10^{-7} , respectively.

If residents were to develop groundwater supplies from within the contaminated groundwater plume, they would be subject to greatly increased health risks, again primarily from arsenic. Under the worst-case assumptions, the calculated risks approached unity, while under the most plausible assumptions the risks were 2×10^{-2} . As mentioned, groundwater from within the plume is not presently used. The calculated levels of risk indicate that the groundwater should not be used until the arsenic concentration in the plume has substantially reduced. It should be noted that the Federal Primary Drinking Water Standard for arsenic, 50 ug/l, calculates to a lifetime cancer risk of 2×10^{-3} .

The limitations of the risk assessment were discussed. The discussion pointed out the inherent inaccuracies in risk estimates, which make assumptions about population behavior patterns and chemical toxicological data. It was pointed out that the risk estimates on the whole tend to be conservative; that is, overstating rather than understating risks in an effort to provide for public safety. It was stated that because of the assumptions inherent in the pathway models and other uncertainties, the risk estimate should be considered no more accurate than plus or minus one order of magnitude.

8.2 CONCLUSIONS

8.2.1 Data Limitations

The samples taken for this RI, with the exception of treatability samples, were analyzed and validated by the CLP. These analyses were considered confirmational level. They required full CLP analytical and validation procedures, and were designed to be legally defensible. These types of analyses are used for risk assessments, engineering design, and cost recovery documentation.

The quantity estimates, results and conclusions presented in this RI are based on this CLP validated analytical data. Data which were rejected in the validation process were not considered when drawing conclusions about the nature and extent of contamination at the site, or when calculating mean concentrations.

Certain field tests were performed, such as pH, specific conductance and temperature measurements on groundwater samples. In addition, some field instrumentation was used in performing the geophysical survey. These field tests provided useful background information, but were not the basis for documenting the contamination at the site.

Various quantity estimates presented in this RI used the CLP analytical data and physical measurements made in the field. For example, the load of arsenic in the Blackwater Branch was determined using the arsenic concentration from the CLP analytical data and flow measured in the field. Field measurements were made consistent with the methods presented in the Field Operations Plan for the ViChem site (Ebasco, 1986).

The risk assessment presented in Section 6 is considered semiquantitative. This is because some of the estimates in the pathway models such as population distributions, the duration of exposure, the amount of soil ingested, and so on, are estimated based on published literature values and were not actually measured at the site.

8.2.2 Recommendations for Future Work

The total extent of the arsenic plume in the groundwater is not known. Specifically, the extent of the groundwater plume to the northwest, west, and south is uncertain. Additional work should be undertaken to define fully the extent of this plume through the installation of monitoring wells in the upper sand aquifer. It should be emphasized that the majority of the plume has probably been characterized and additional wells would be necessary only to define the outer limits of the plume.

Also, the reason for the very high concentration of arsenic in well EW-4M, which is northwest of the site, is unknown. While this well is in the upper sand aquifer in the direction of the plume, the arsenic concentration here is two orders of magnitude higher than anywhere else. There may be another source contributing arsenic to this well, or this may be the remnant of a highly contaminated arsenic slug moving through the upper sand. The reason for this high peak should be determined. This would best be accomplished by installing additional wells between the plant site and well cluster EW-4.

The surface and subsurface soils have been fairly well characterized in this RI. Sufficient data is available to establish general locations of soil arsenic contamination. However, if soil remedial actions are taken in the future, sampling will be necessary to assess definitively the areas for removal based on action levels.

A number of estimates were made regarding the partitioning of arsenic to the aquifer soils. Despite having a large data base, the estimated partition coefficients ranged over a broad spectrum and even appeared to vary as a function of the arsenic concentration in the soil and water. How arsenic partitions to the saturated and unsaturated soils, particularly in terms of desorbing from both, is very important in terms of the future leaching of arsenic into the groundwater and arsenic's transport off-site via the groundwater.

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For these reasons, column leaching tests should be performed on the site soils. If properly designed, these tests can help determine a) the natural leach rate of arsenic from the soils, b) arsenic's attenuation characteristics on the soils, c) how the partition coefficient varies with arsenic content in the soils and d) at what point arsenic will no longer desorb from the soils. All of the above are very important parameters to define arsenic's overall fate and transport at the plant site.

8.2.3 Recommended Remedial Action Objectives

The data collected in this RI show that the groundwater in the upper sand is discharging into the Blackwater Branch and impacting the downstream sediments and surface water. While this groundwater is not presently used by area residents, the discharge of the groundwater should be stopped to eliminate the load of arsenic into the surface waters.

The soils on the site are contaminated with arsenic at some locations. This contamination can leach into the groundwater, providing a continuous source of arsenic. Also, although the risks to area residents from the soils are below target levels, future uses of the plant property could be limited by the arsenic contamination in the plant soils.

The soils below Building #9 are contaminated with arsenic. However, the floor of this building consists of over one foot of concrete and brick, and the area around the building is paved. Therefore the potential for percolation of rainfall through these soils is low, although some arsenic may be solubilized by a fluctuating water table. Risks to people contacting these soils are low because the floor provides an effective barrier to the contamination. Assuming that a groundwater remediation system could capture arsenic solubilized by a fluctuating water table, the only reason to remove the soils below this building would be if the plant property were reused for a different purpose in the future. If the existing "cap" is removed through some future use scenario, then it will be necessary to define the extent of contamination below the plant buildings and the paved areas on the plant property.

The dust inside of the chicken coops contained substantial quantities of various metals. Measures should be taken to ensure that public access to the dust in these coops is minimized or eliminated.

The recommended remedial action objectives for the ViChem plant site may be summarized as follows:

- o Eliminate off-site contaminated groundwater migration so that the instream standard of 0.05 mg/l total arsenic is not violated in the Blackwater Branch;

- o Minimize the leachate generated from the contaminated soils to the groundwater;
- o Eliminate exposure pathways to contaminated soils and dust; and
- o Restore the aquifer for eventual reuse.

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